1986 NASA AUTHORIZATION

HEARING

BEFORE THE

SUBCOMMITTEE ON TRANSPORTATION,
AVIATION AND MATERIALS

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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1986 NASA AUTHORIZATION

TUESDAY, MARCH 5, 1985

HOUSE OF REPRESENTATIVES, COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS,

Washington, DC.

The subcommittee met, pursuant to notice, at 1:40 p.m., in room 2325, Rayburn House Office Building, Hon. Dan Glickman (chairman of the subcommittee) presiding.

Present: Representatives Glickman, Reid, Gordon, Lewis, Boehlert, and Packard.

Mr. GLICKMAN. Why don't we go ahead and begin. Today I would first tell the witnesses that unfortunately the House is in session, and we will be having several votes this afternoon. We will do our best to kind of manipulate the time as best we can. But I just want to let everybody know that we will be forced to go to the floor and vote and come back.

On March 3, 1915, a little noticed but tremendously significant event took place. It was on that date, almost exactly 70 years ago, that President Wilson signed a Naval Appropriations Act, to which was attached an obscure rider establishing the National Advisory Committee on Aeronautics.

The enabling language was a masterpiece of simplicity and comprehensiveness if measured against modern-day legislation. It directed NACA, the advisory council, to "supervise and direct the scientific study of the problems of flight with a view to their practical solution."

With that charter, and only modest resources over the years, NACA and its successor agency, NASA, have poured forth an unending stream of new aeronautical research and technology that has served our country well both in wartime and in the international civil marketplace. And in my view, it has been an exceptional bargain for the taxpayers and an example of how government ought to work.

Yet, despite this, the first A in NASA has frequently come under challenge. I might add as a historical footnote that such challenges have usually come just before a major war, with the war reaffirming once again the value of having a Federal research capability in aeronautics. Hopefully, we are not about to suffer a war, and I am not encouraging that today.

But clearly, NASA aeronautics has been under challenge in recent years. This year we have a severe budget deficit with which we must deal by holding or in some cases reducing expenditures,

and all agencies must participate. So in aggregate, I feel the NASA budget for 1986 is a responsible one, given the times we are in.

Nevertheless, I do want to make sure that the limited funds available are applied to the highest-priority research areas. For this reason, I recently established a new group to review in detail the NASA aeronautics budget request. Composed of experts from industry, academia, and the military, and known as the Congressional Advisory Committee on Aeronautics, this group spent many hours since last fall examining virtually all of NASA's projects and in considering a number of larger issues.

We will hear the results of this work later in the hearing, following a presentation by NASA of its budget request for next year.

Mr. Lewis, my ranking member, will be here shortly, but his statement should appear in the record immediately following mine.

[The opening statement of Mr. Lewis follows:]

NASA Aeronautics Authorization Hearing

Opening Statment

By

Hon. Tom Lewis

Mar. 5. 1985

Thank you Mr. Chairman. I want to join you in welcoming our distinguished witnesses who are here today to enlighten us on NASA's aeronautics program and also what the future holds for us in aeronautics.

When the President's budget was announced and the earlier published reports of the demise of NASA's civil aeronautics program were proven wrong, there was a collective sigh of relief in the aeronautics community. And in view of the very difficult challenges facing the Office of Management and Budget, it would not have been surprising to see large cuts in a discretionary program such as this which cannot be categorized as either a defense program or a safety net program. Surely this budget, which does provide a small increase for inflation, reflects the strong committment by this administration to the importance of aeronautical research.

None the less, some choices have to be made. And we in Congress bear a responsibility to ensure that the aeronautics program which is supported by all tax payers is the kind of broad-based program that will support all Americans.

MR. CHAIRMAN, YOU ARE TO BE COMMENDED FOR ESTABLISHING THE CONGRESSIONAL ADVISORY COMMITTEE FOR AERONAUTICS TO ASSIST US IN A REVIEW OF NASA'S PROGRAM. THIS SHOULD PROVE VERY HELPFUL TO US IN OUR DELIBERATIONS, BUT IN NO WAY DOES THIS DIMINISH OUR RESPONSIBILITY. I LOOK FORWARD TO HEARING MR. ALBUM'S SUMMARY OF THIS COMMITTEE'S VIEWS.

THERE ARE MANY CONFLICTING VIEWS ON WHAT NASA'S AERONAUTICS PROGRAM SHOULD BE. JUST AS WE CAN ALL AGREE ON THE IMPORTANCE OF A BALANCED BUDGET, WE CAN ALSO AGREE THAT NASA SHOULD PROVIDE THE AERONAUTICS INDUSTRY WITH THE NECESSARY TECHNOLOGY TO DEVELOPE A SUPERIOR PRODUCT AT A COMPETITIVE PRICE. IT'S WHEN WE GET TO SPECIFICS THAT THE DISAGREEMENTS BEGIN.

THE PROGRAM THAT NASA HAS PROPOSED FOR FY '86 DOES SUPPORT A WIDE RANGE OF TECHNOLOGIES FOR THE FUTURE. IT ALSO APPEARS TO BE CONSISTENT WITH THE PHILOSOPHY THAT GOVERNMENT SPONSORED RESEARCH AND TECHNOLOGY SHOULD FAVOR THE BASIC GENERIC TECHNOLOGY OVER TECHNOLOGY DEMONSTRATION, UNLESS OF COURSE IT IS IN SUPPORT OF OUR MILITARY. I STRONGLY SUPPORT THAT PHILOSOPHY. I BELIEVE THAT WITH THE LIMITED FUNDS THAT WE HAVE TO WORK WITH THIS YEAR IT OFFERS US OUR ONLY HOPE FOR CONTINUED PROGRESS IN AERONAUTICS.

MR. CHAIRMAN, AS I BELIEVE WE CAN CONTINUE TO MAKE GREAT STRIDES IN AERONAUTICS, I AM VERY INTERESTED IN HEARING DR. HAZEN'S REVIEW OF THE NATIONAL RESEARCH COUNCIL'S STUDY ON THE POTENTIAL FOR AERONAUTICS IN THIS CENTURY. I AM VERY OPTIMISTIC OVER THE FUTURE OF AERONAUTICS AND I AM GLAD THAT HE IS HERE WITH US TODAY TO SHARE HIS VISION OF THIS FUTURE WITH US.

I WOULD ALSO BE INTERESTED IN HEARING DR. HAZEN'S VIEWS ON THE PROGRAM NASA HAS PROPOSED FOR NEXT YEAR, AND WHETHER, GIVEN THE SEVERE BUDGETARY CONSTRAINTS THIS YEAR, HE BELIEVES IT IS CONSISTENT WITH HIS VISION OF THE FUTURE.

THANK YOU MR. CHAIRMAN.

Mr. GLICKMAN. Mr. Boehlert, do you have any comments?

Mr. BOEHLERT. No, Mr. Chairman.

Mr. GLICKMAN. It is a pleasure to welcome Dr. Jack Martin, the associate administrator for aeronautics programs at NASA.

It is a pleasure to have you here today. Your entire statement will appear as a part of the record, although I would tell you that when you summarize your statement, that will also appear in the record separately as well, but why don't you go ahead and proceed.

Mr. MARTIN. Thank you, Mr. Chairman.

Mr. GLICKMAN. I think our witnesses today are fairly limited. I think it's most important to hear from you. But I would instruct all the witnesses to do whatever they can to try to keep their testimony, if possible, to no more than 15 minutes.

Mr. MARTIN. All the witnesses?

Mr. GLICKMAN. Everybody. But do your best. I mean if you overextend, we will give you some leeway.

STATEMENT OF DR. JOHN MARTIN, ASSOCIATE ADMINISTRATOR FOR AERONAUTICS AND SPACE TECHNOLOGY, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY RAYMOND COLLADAY

Dr. MARTIN. Mr. Chairman, thank you. I appreciate this opportunity to be here. I have with me my deputy, Dr. Raymond Colladay, and my directors are with me as well to answer any questions that might come up later.

I accept your invitation to submit my formal statement for the record and will, as you suggested, informally address the key points of the statement.

Our purpose in this budget is to look ahead to the needs of the aeronautics community through the turn of the century. My presentation will discuss some of the things that will be important to the future of the aviation community over that timeframe and, in view, are deserving of your support and encouragement.

I believe that the proposed program meets your desires for a balanced effort in both disciplinary and systems research activities within the constraints of the overall Federal budget.

It will allow NASA to maintain outstanding aeronautical research and development capabilities, represented by the facilities and staff at Ames, Lewis, and Langley Research Centers. It will permit enhancement of the Nation's vital technology base critical to the continued superiority of U.S. aircraft through the high-leverage research in the traditional disciplines in systems research areas such as advanced turboprop and numerical aerodynamic simulation.

It is important to note that most of NASA's aeronautics research has common applicability to both military and civil aircraft and that the needs of aeronautics and space technology are in the process of beginning to converge; for example, high-temperature materials, aerodynamic heating and control, and guidance systems for logical areas of research.

Because some of the members are new to the committee, I would like to begin by describing three important areas of aeronautical research where the contributions made by NASA have been central and which also illustrate the lengthy development periods that are associated with laboratory-to-industrial application.

The three technical areas I have chosen are: supercritical aerodynamics; tilt rotor technology development, and energy-efficient propulsion technology.

The first chart shows some of the pioneering research on aerodynamic airfoils in the period from 1962 to 1974, during which a family of supercritical airfoils were analyzed to minimize large increases in the drag that occurs at transonic speeds. Drag reductions of 15 to 20 percent are now possible, which allows increased cruise speed and increased maneuverability for fighter aircraft.

This Langley invention has now begun to find its way into wings designed for the 767 and the McDonnell F/A-18 aircraft. However, prior to acceptance as a proven technology, it was necessary to conduct extensive flight research. The NASA F-8/supercritical wing with the transport-type design and the joint NASA-Air Force transonic technology F-111 variable-sweep fighter wing configuration are illustrated in the center of the picture.

The second major breakthrough was in rotorcraft technology. As illustrated in the next figure, the tilt rotor aircraft operates as a helicopter at low speeds and is a fixed-wing aircraft and propeller-driven at higher speeds. This permits vertical takeoff and landing and longer cruising range and speeds up to 400 miles an hour.

The concept of the tilt rotor began in about the late 1940's. During the 1950's, XV wind tunnel and flight programs were investigated to determine the feasibility of the tilt rotor concept at low

speed and identify key technology issues. Subsequent research verified potential solutions to the dynamic stability problems evident in the XV-3.

Early in the 1970's, the joint NASA-Army XV-15 tilt rotor research aircraft program was launched, and in the early 1980's two proof-of-concept research aircraft and other supporting research has provided the confidence level necessary for DOD to initiate full-scale engineering development of the joint services advanced vertical-lift aircraft, the JVX, leading to the production of over 500 aircraft in the early 1990's. That's about 50 years from start to finish in that particular case. Civil applications are expected to follow the JVX development.

The third example is energy-efficient propulsion, where NASA research on transonic compressor aerodynamic and turbine film cooling in the 1960's provided the basis for revolutionary advances in the propulsion system efficiency. Later, the NASA energy-efficient engine, called E3, program from 1979 to 1983, conducted with General Electric and Pratt & Whitney, advanced the state of the art of key component areas.

At the conclusion of the E3 program, the components were integrated to evaluate performance structures and engine dynamics at the systems level. Today, these technologies provide over a 15-percent increase in engine fuel efficiency over contemporary designs and are being applied in the world's most advanced engines, the P&W PWA-2037 and the General Electric CF6-80C.

As these examples illustrate, it takes many years, often a score of years, from first principle to product application of technology. This process usually requires the verification of technology effectiveness either in flight or large-scale system tests, and this is best accomplished through Government-industry cooperation.

With that as background, I would like to discuss the budget requests for the coming year and some recent changes in headquarters management. In order to more effectively manage the interrelated elements of our aeronautics R&T programs and to more closely align headquarters management with our research centers, I reorganized the Office of Aeronautics and Space Technology since my last testimony before this committee.

This figure shows the new OAST management structure which was implemented in August 1984. To provide the necessary centralized planning, budget allocation, and vehicle class program integration, we have established the Offices of the Director of Aeronautics, held by Mr. William Aiken, and Director for Space and Director for Institutions. The detailed direction of the program, the tracking and the reporting functions for both aeronautics and space technology programs are handled by the disciplinary divisions. The research centers—Ames, Langley, and Lewis—are responsible for implementation of these approved programs and report directly to me.

Moving on to our budget request, the fiscal year 1986 aeronautics request totals $354 million, and it's shown here in comparison with previous years' budgets. The systems technology line shows a slight decrease, offsetting growth in turboprops with the reduction in composites.

Further details of the budget have been provided in material previously to the subcommittee. I will summarize the key elements for you today.

The applicability of disciplinary research to specific classes of aircraft is a way to view NASA budget as perceived by various sectors of the aviation community. Such an analysis of the budget for fiscal year 1986 is shown in the picture. In the upper portion of the chart, labeled "Direct," the R&T base and systems technology resources are divided into general aviation, transport, high performance, rotorcraft, and generic categories.

From this analysis, it is seen, for example, that $11.1 million of NASA funds are directly applicable to general aviation aircraft and $52 million of the $354 million total is directly applicable to rotorcraft. However, it is important to recognize that there are additional indirect benefits to these vehicle classes from generic research or from research directly applicable to other vehicle classes.

The lower portion of the figure, labeled "Indirect," quantifies these additional benefits, that for general aviation, as an example, are equivalent to an additional $72.4 million of research.

In addition to the talented researchers and funding to support their activities, an integral component of NASA's aeronautical research and technology program is the agency's research facilities. These are national assets, considered by industry and DOD to be central to the development of superior military and civil aircraft in our country.

Examples of major new facilities capabilities are shown in the figure. The national transonic facility, which has been demonstrated over its entire operating envelope in research testing, is beginning. The 40- by 80- by 120-foot subsonic wind tunnel is to have its 40- by 80-foot circuit in operation in the spring of 1986, and the 80- by 120-foot section in operation by late 1987, and the numerical aerodynamic simulation facility, which you will hear more about shortly.

Now I plan to describe the key elements of the aeronautics R&T base and systems technology programs, emphasizing recent accomplishments or directions for continuation in fiscal year 1986. I will begin with aerodynamics.

The aerodynamics programs provide the computation methods and experimental data base required to develop aerodynamic concepts and configurations for future civil and military aircraft. Wind tunnels and computational facilities operated under these programs also provide vital capabilities used by the entire U.S. aeronautics community.

The numerical aerodynamic simulation program shown in this figure is a pathfinder tool for the development of new advanced analysis and predictive techniques for aerodynamic research and aircraft concept development. These capabilities will also support important research and other computationally intensive disciplines such as chemistry, structures, materials, weather, and climate.

Full-scale developments for the NAS system began in fiscal year 1984. The initial high-speed processor CRAY-2 is scheduled for delivery in September 1985. At that point, all of the major pieces of the initial system will be in place, and intensive tests and integration activities will begin.

The primary objective for fiscal year 1986 is to activate the interim initial operating configuration by July 1986, with high-speed processing networks, interactive graphics work stations, and long-haul satellite and land line communication links between research centers.

This computational capability will be the most advanced in the world, with 256 million words of memory and a sustained operating speed of at least 250 million floating point operations a second, equivalent to 4 to 6 times current capabilities. It will provide full on-site and limited off-site access for the user community.

Following a test of the long-haul communication system by fiscal year 1986, the system will be upgraded to provide nationwide access. In fiscal year 1986 we will complete construction of the NAS building. We have often referred to this effort as the centerpiece of the aeronautics program in the 1980's.

As we approach operational status, I can assure you that the payoff from this world-class capability will be immense. It won't replace wind tunnels, but it will make wind tunnels more effective. It won't be a tool that will benefit just one vehicle type, but a tool that will benefit all vehicle types. It will provide a window into the fundamental physics of fluid flow, and it will enable designers to consider integrated engine and airframe configurations of unprecedented complexity. This is the kind of pathfinder research that has been the hallmark of the NASA aeronautics program and its predecessor, NACA, for 70 years.

Computational fluid dynamics is emerging as an essential and powerful tool for improved understanding of both external and internal flow physics. It provides the capability to simulate conditions and flow phenomena which are difficult to measure physically and provides results which can be readily visualized and manipulated to support design trades and detailed analyses.

As shown, this technology continues to evolve steadily from the capability to simulate less sophisticated flows over basic component shapes to the ability to calculate real flows over complete aircraft and through internal passages of gas turbine engines. The goal for fiscal year 1986 is to combine complex flows with full aircraft and engine configurations operating over realistic flight conditions, as illustrated on the right of this figure.

Reducing the viscous drag caused by skin friction is a key objective in the aerodynamics research, since it accounts for roughly one-half of aircraft total drag at cruise speeds. Three techniques are being explored and are shown on the next chart: laminar flow control where suction near the leading edge is employed to maintain low-drag laminar flow; natural laminar flow airfoils designed so that favorable pressure gradients exist over extensive portions of the airfoil to assure laminar flow; and advanced concepts to reduce turbulent drag on fuselage, where laminar flow is difficult to achieve.

An F-14 aircraft with variable-sweep capability will be flown in fiscal year 1986 with a number of natural laminar flow wing gloves of different wing gloves to study the effects of sweep angle and the conditions under which transition from low-drag laminar flow to high-drag turbulent flow will occur.

Laminar flow control tests on the Lockheed JetStar will be completed in fiscal year 1986 with the testing of Lockheed and Douglas wing leading edge concepts under representative flight conditions. The successful demonstration of reliable, maintainable laminar flow over the leading edge will be an important milestone in aircraft engineering.

In the area of turbulent drag reduction, industry flight tests have confirmed that one NASA-developed concept called riblets can provide net turbulent drag reductions of approximately 6 percent. An alternative turbulent drag reduction approach, large eddy breakup devices, will also be pursued in wind tunnel and flight tests.

Moving now to materials and structures, the research and technology program provides the foundation for advances in new and improved materials, structural concepts, and advanced analytical methods. Lightweight structural concepts and advanced analytical techniques represent key areas for future high-speed aircraft.

To meet this need, our current program is developing imaginative design concepts for high-temperature structures operating at up to 1,800 degrees Fahrenheit. It is essential that these structures be extremely lightweight for greater aircraft range and still be able to maintain strength and shape under optimal loads.

One promising concept under investigation, illustrated in this figure, is the use of load-carrying honeycomb panels made of high-temperature nickel-based superalloys which are used extensively in the hot section of modern jet engines. During the past year, a 20-panel array of this honeycomb material was tested in the Langley high-temperature tunnel under hypersonic conditions. The structure withstood local temperatures up to 1,850 degrees Fahrenheit, successfully demonstrating the concept validity.

Concurrent with this test, a comprehensive analysis of fluid flow over the panel predicted effects leading to local hot spots and thermal bowing. A curved superalloy honeycomb test panel, illustrated in the figure, has now been fabricated and will be tested. Further work on thermal load prediction capability will also continue during the coming year.

The performance and durability and replacement costs associated with U.S. aircraft gas turbine engines are dependent upon materials available for critical hot section components. Use of ceramic materials in gas turbine engines offers the potential of higher temperatures, lower costs, greater corrosion resistance, and the added benefit of no strategic materials.

Some of the recent advances in ceramics are shown here. An advanced 3D structural analysis capability was developed to predict the probability of failure in geometrically complex engine components. This represents an initial step in the current effort to understand failure modes more clearly and to develop design methodologies which can reduce component sensitivity to these modes.

An extensive effort is ongoing to develop better sintering processes by which components are formed and to optimize the material additives that are used to enhance the material microstructure. During the past year, significant advances were made in both of these areas. Silicon carbide, when sintered by a new process, demonstrated a 60-percent increase in bending strength. In the case of

silicon nitride, a new nitrogen sintering process demonstrated the potential for improved structural performance at high temperatures.

Now I will talk about propulsion a few minutes. NASA's intermittent combustion engine research encompasses both in-house and contractor efforts. During the past year, these study and research activities prompted NASA to concentrate research for advanced general aviation powerplants on the rotary engine. Its performance, installability, and multifuel capability make it an outstanding candidate for propulsion systems for light aircraft and other applications in the early 1990's.

In fiscal year 1984, under contract with John Deere, a rotary engine research rig was successfully operated on jet fuel using a stratified charge combustion principle. Studies of a ceramic rotor concept were also completed, showing feasibility of this efficiency enhancing innovation.

A follow-on contract with Deere is planned to exploit the new stratified charge rotary engine. Component analysis will be extended to include the stationary housings, thereby defining an overall thermal model for low-heat rejection rotary engine.

A major new internal flow computer code will be validated by laser measurements in a transparent rotary engine rig. Small turbine engines are very important to the many types of aircraft, including general aviation, commuters, helicopters, and cruise missiles. Current small-engine efficiencies are 8 to 10 percent less than large engines. Further, the design and analysis techniques for large-engine components are inadequate for accurately predicting the performance of small engines.

Mr. GLICKMAN. Excuse me. We have all of this material, I think.

Dr. MARTIN. Yes.

Mr. GLICKMAN. Do you have, for instance, key issues or a summary, perhaps, at the end or something?

Dr. MARTIN. I think I would like to look through the charts that deal with the planning for the future.

Mr. GLICKMAN. All right.

Dr. MARTIN. Those are the last half-dozen.

Mr. GLICKMAN. OK.

Dr. MARTIN. Well, there is one issue. That deals with the oblique wing. May I take a few minutes on that?

Mr. GLICKMAN. Surely.

Dr. MARTIN. The preliminary design of an oblique-wing research aircraft, which is illustrated here, is now being initiated. This is a joint program with the Navy to develop an experimental aircraft with a fiscal year 1989 flight program.

The purpose is to extend the technology to transonic and supersonic speeds. The aerodynamic advantage of the oblique wing is shown on the lower left, where you see the lift-to-drag ratio is greater at all speeds than a fixed 45-degree sweep. The loiter/dash superiority is superior also, as you see in the lower right.

The Oblique-Wing Program builds on the significant technology base which started in 1945. We have had wind tunnel tests, remotely piloted vehicle research tests, and manned low-speed tests. The next step in the technology development is the highly complex interactions of control systems and the time-veering elastic behav-

ior of the oblique wing in transonic and supersonic maneuver in flight. These cannot be carried out on the ground and must lead to flight tests.

The existing NASA F8 digital fly-by-wire research aircraft will be modified, as shown, and will be the test bed for the flight program.

In planning for the future, we've had considerable advice from a number of informal and formal advisory groups and special ad hoc study groups, not the least is the Office of Science and Technology Policy. We have undertaken comprehensive strategic and long-range planning activities for establishing our priorities, and we see some revolutionary possibilities for the future. I am just going to flip through a few of these.

The first is an advanced subsonic transport which ought to double fuel efficiency and significantly reduce operating costs, the key technologies being high-aspect ratio wings and laminar flow control and turboprop propulsion.

Advanced computers in the wings with low-cost and high efficiency being special drivers in this competitive growing market, the technologies that are most relevant are turboprops, natural laminar flow, and low-cost airframe structures.

Advanced rotorcraft is another example where quiet single-pilot operations are required, all weather, speeds to 200 knots, with the key technologies being lightweight structure and high-speed rotor systems.

Supersonic transport, if it's going to go anywhere, is going to have to be faster and more economic than the Concorde. It might also have military applications. Here is a family concept in this chart, where the essential technologies are high temperature, variable cycle propulsion systems, and supersonic laminar flow.

Also, a supersonic STOL, short takeoff and landing aircraft, which could operate from short or damaged runways and from appropriate Navy ships. Cruise mach number would be 2.5 to 3.5, and the driving technologies would be integrated flight control systems and high-thrust-to-weight-ratio engines.

And finally, a hypersonic airliner, which reflects a civil vehicle concept, operating in the atmosphere with speeds up to mach 12. For such vehicles, new air-breathing propulsion technologies, control techniques, and high-temperature materials and structures will be required.

I think we have a program, Mr. Chairman, that meets the needs that I am sure you have and we have for maintaining aeronautical technology and aviation in the United States preeminent in the world. The budget request for 1986 builds on the momentum we have, and I solicit your continued support. I thank you for your attention.

Mr. GLICKMAN. Thank you, Jack. We appreciate it. I am sorry to abbreviate your testimony. It's just that we'll have more time for questions this way.

First of all, after you testify, Harvey Album will be testifying on the work of the Congressional Advisory Committee that we formed to go over your budget. And I don't think there is time today for you to comment in detail about the specifics of the recommendations other than to compliment NASA for their openness and basi-

cally letting this group have access to your shop and figure out that maybe there may be some changes that they're going to propose.

So after this hearing is over, I would like very much for you to provide this committee with some sort of formal response to their recommendations.

Dr. MARTIN. Your staff and Dr. Album have been most kind and suggested that possibility, and we would like very much to do that. We do not agree totally with the CACA findings.

Mr. GLICKMAN. Right. Well, I think that once we get that response, it will be made a part of the record because it needs to be. And I know that this thing wasn't set up to be a rubberstamp for you or a rubberstamp against you, and I think that they have ideas that you might consider and others that you may have reasons why you can't agree with them. But I just want to provide a process by which you can comment on each one of the major changes that they propose, whether it's on a particular item of systems technology or just general research dollars, and give us your rationale why you think it's good or not good.

Dr. MARTIN. Thank you for the opportunity.

Mr. GLICKMAN. Yes. The other thing that I would have to tell you is that I have had some feeling—and I am happy the NASA budget is as amplified as it is—that there is a tendency in NASA as there is in a lot of research institutions to just keep doing what you've been doing before and maybe not sit down and think, "Should we just ax this program, because there's no reason to continue it? We're not finding anything new."

Or maybe in the reevaluation process the tendency in Government sometimes is just to continue programs because they have staff people working on them and not necessarily independently evaluating them. And that's one of the things we asked the Congressional Advisory Committee to come in and take a look at.

I wonder if you might comment on my thoughts in connection with your budget submission this year.

Dr. MARTIN. Based on what you just said?

Mr. GLICKMAN. Yes.

Dr. MARTIN. There is that perception, I think, and it's not totally true that we keep doing the same things year after year after year. I suspected that might be the case myself, and I have talked at some great length with the research center directors.

What really happens—and I guess this was part of my learning process—is that we make the mistake of keeping the same names for a changing program, and the center directors are continually looking at the elements of their research program and making changes in it which show up at our top level but which don't show up with name changes in the documents that we talk about here, which are a reasonably highly aggregated level of accounting.

So what I am saying is that there is that change going on. It's going on continually. It's not huge seismic events, but just the almost day-to-day kinds of changes going on. So the change is there, it's just not as evident as it ought to be, I think.

Mr. GLICKMAN. Well, you know, a few years back, 4 or 5 years ago, I went to the Lewis Center in Cleveland, and one of the researchers commented to me privately. He said, "This place doesn't

have the spontaneity that it used to have." And you know, when I pressed him on it, he says, "Well, you know, in the old days there was a lot more excitement and aviation was in its infancy."

But you know, NASA is one of the few agencies that has kept some degree of spontaneity, primarily because you're working almost exclusively on the research side of the picture. And as I look through particularly the item on the budget entitled "Research and Technology Base," which is growing, $239 million from $228 million last year, there is a lot of room there for a variety of basic research projects.

And I would just hope that in your budget request you keep in mind that the original function, why Congress created this organization and we want you to continue doing business, is so that there is kind of a spontaneous research base there that we have programs that generate some excitement and don't merely just exist because they have existed in years before.

Dr. MARTIN. I would like to respond to that if I might.

Mr. GLICKMAN. Surely.

Dr. MARTIN. The perception of one of the unnamed researchers at Lewis about spontaneity might have been on the mark. I can't say from firsthand experience because I wasn't associated with NASA at that time.

It's fair to note that Lewis was given a new director about 2½ or 3 years ago.

Mr. GLICKMAN. This was before the new director.

Dr. MARTIN. I know that, but that was my point, that the new director has shaken things up some considerable amount. He's a very energetic person and has made it a more spontaneous activity. In fact, within the past year, you know, I think, that a large portion of Lewis was reorganized, in aeropropulsion in particular, and I am sure that there is a good deal of spontaneity now in that area. And there is that feeling, I think, at Lewis of spontaneity, probably not even across all the divisions, but nonetheless there is excitement there.

Mr. GLICKMAN. Well, I just mentioned it. Now, I am not sure exactly what was in that reorganization, but I understand it has caused a net loss of researchers.

Dr. MARTIN. If you care to discuss that, Dr. Colladay was a major participant in that activity, and he can probably tell you, in more detail than you want to know, what went on there.

But let me just finish, if I might.

Mr. GLICKMAN. Sure.

Dr. MARTIN. There are also new center directors at Ames and at Langley, and at each of them it is evident already that our moving to shape the organization in ways that they think are useful and fit their ways of thinking about the problem, and I am sure that they'll be exciting—and they'll continue to be exciting—with this new leadership.

Would you like to talk a little about it?

Mr. GLICKMAN. Just briefly, what was the essence of your reorganization of the Lewis Center, which of course does all your engine work as well as other related things, deicing and other kinds of things?

Dr. COLLADAY. I think, in part, Mr. Chairman, the reorganization of Lewis, of the Aeropropulsion Program, was a response to what we felt were some exciting opportunities that we were facing for propulsion.

Propulsion has always been a pacing technology for new vehicle systems, and in recognizing that opportunity that was before us in the program and the limited resources that we had, we decided that it was appropriate to take stock of where we were going, what breakthroughs were possible in propulsion that would pace new vehicle systems, and organize it in such a way to attack the technology for the future.

I think the esprit de corps at Lewis now, if you went back—and we would like to invite you to visit Lewis again and see the change that has taken place—I think you would find a different picture now than you saw perhaps 5 years ago.

Mr. GLICKMAN. All right. I don't want to go into great detail, you know. Some of those, I guess adversely affected, have indicated their concern. But, you know, I am not going to get involved in the day-to-day management of your centers. It's just that, from what you are telling me, there is a method in what you are trying to do to enhance the productivity and spontaneity of the centers. Is that correct?

Dr. COLLADAY. Yes, sir, it is, very much so.

Mr. GLICKMAN. All right. Let me go on for a moment. I want to talk about the hypersonic cruise. The committee asked NASA for a long-range plan, and I wonder if you might summarize the key points of the plan and what elements of that plan are included in this request.

Dr. MARTIN. Again, Dr. Colladay was a major architect in that, and I think I will leave it to him to respond to that, if I might.

Dr. COLLADAY. As I mentioned, in aeropropulsion as it applies to vehicle classes for the future in the area of high-speed flight and hypersonics, that the importance of propulsion also comes through in that the pacing technology is in scramjet propulsion and air turboramjet advanced engines.

Those two elements that were in the plan are addressed in our budget request as is the area of accelerating high-temperature structures that is crucial for advanced high-speed vehicles. And, a companion to that, to the R&D program in structures, is the new high-temperature structures tunnel at Langley, which is an enabling facility for continuing this research.

And a number of the base technologies that were highlighted in that plan are addressed in a limited way in the budget request. We are still trying to pull together the wide-ranging views of the industry and NASA, the university community, and DOD on what the right program is and what makes sense in high-speed hypersonic flight.

Mr. GLICKMAN. Well, my impression is, not very much of this plan is contained in this budget recommendation. That is, there was $5.3 million, an augmentation that was lost out in the budget process. And I am looking at the back of this plan where it says, "Hypersonic program funding requirements by element and year," and the first year would be $6 million.

I mean you're talking about a fairly significant effort, and I think Congress needs to make that policy choice. But we were serious when we basically indicated last year that we wanted at least to pursue this program and at some point make a decision on whether we wanted to move ahead or not.

I guess I am kind of concerned that there is not much of the hypersonic effort in the budget that we have before us.

Dr. COLLADAY. Well, it is a concern. We think we're addressing the long-lead technically critical elements of the program. But before we embark on a major buildup of an effort scoped in the technology plan, we have to mobilize the industry and the participants that would be sharing in this effort, and that consensus hasn't developed yet.

We are currently involved in working with the industry to pull the views together on what the program should be, but we didn't feel that we could launch into that kind of R&D buildup until that consensus was built and emerged, and we are just in the process of doing that.

Mr. GLICKMAN. All right. Well, I only would like to reemphasize today that as far as I am personally concerned, I think this is a very important issue for the long-term lead of American aeronautics, and I personally intend to keep a watchful eye over you—and not just you, but OSTP and others as well—to try to develop a responsible program in hypersonics.

I mean I don't want to get into something that's going to cost as much as the space station, but on the other hand I think it's something that has a great deal of possibilities for us in the future. And I want to see Americans take the lead, and not the Airbus folks or, you know, somebody else.

Let me just ask you a couple of more questions. You have proposed the termination of the advanced composite structures program. Is that correct?

Dr. MARTIN. That is correct.

Mr. GLICKMAN. OK. I just want to know basically why did you decide to terminate it? Was it just a priorities choice?

Dr. MARTIN. It was a priorities choice, but it's something that would have happened in any case, I think, even if the budget had been somewhat larger.

Dr. Colladay and I had reviewed that program at the contractors' plants that were doing it, and in general were dissatisfied that we had the program that we thought that we ought to have had, and were in the process of making changes. I would say that the budget process only accelerated what we were going to do; it didn't really change the need to do it or the outcome that would have taken place.

Mr. GLICKMAN. How much money did the contractors put into this work, do you know?

Dr. MARTIN. I think altogether well over $100 million.

Mr. GLICKMAN. Yes. OK. Well, just one final question. The advanced turboprop program, both it and the NAS, the simulator program, have very strong support from Congress. I compliment you on carrying out the congressional intent by fully—reasonably fully—funding both programs. Is it your intention, and implicitly OMB's acceptance, that the advanced Turboprop Program will be

funded out into the outyears at the levels that we have talked, and you've talked about, beforehand?

Dr. MARTIN. We've submitted it as a baseline change, and it was accepted as such, and I believe it is a fixed part of the program and the hustling is over.

Mr. GLICKMAN. OK. So we're reasonably comfortable that in future years this program will be funded in connection with how you propose it this year?

Dr. MARTIN. Yes, sir.

Mr. GLICKMAN. OK. Same thing with the National Aeronautics and Space Administration facility as well?

Dr. MARTIN. Indeed.

Mr. GLICKMAN. Any new facilities that you think would need be included in the future?

Dr. MARTIN. Well, the major one is the altitude wind tunnel, which has a number of capabilities, mainly icing research and some propulsion capabilities as well. It's a major expenditure, but I would say fundamentally that one.

Mr. GLICKMAN. You bring up icing. It wasn't even on my question list, but how much work are you doing on aircraft deicing now?

Dr. MARTIN. I am not familiar with that.

Are you? Do you have anything on that?

Mr. AIKEN. The program is probably——

Mr. GLICKMAN. Why don't you state your name for the record and talk into the mike, too, up here, and stand up.

Mr. AIKEN. Aiken, from OAST. There's roughly a million of R&D funds in icing. About two-thirds of it goes into the activities related to rotorcraft. Now, remember, when I say "a million dollars in R&D funds," that includes inhouse support, not contract stuff only, and the other third of it is for light aircraft and other activities connected with the problem of icing at low levels, sometimes a bit on tactical missiles.

Mr. GLICKMAN. How much of that is university—is the contracting-out university work?

Mr. AIKEN. Contracting out is generally university work. It probably adds up to about $150,000 a year. I would like to be able to correct those numbers for the record if they aren't exactly correct.

Mr. GLICKMAN. All right. You know, I still remember the Air Florida crash, and that, at the time, I was shocked to have seen that there were no standards for the amount and percentage of glycol that would be mixed with water, and still aren't. There are circulars out, but it struck me how our knowledge of preventing icing conditions, at least from a practical point of view, haven't improved very much in many, many years, and I just hope that there is some feasible end to the kind of research that you're doing on icing that will maybe produce some tangible results.

Mr. AIKEN. Well, this is one of the more complex problems in aeronautics.

Mr. GLICKMAN. Excuse me. I have to make a quick phone call. I wonder if you might answer that question, and Mr. Boehlert will have an opportunity to ask questions, and I will be back. And if I am not back in a few minutes, go ahead to the next witness. I will be right back.

Mr. BOEHLERT [presiding]. Thank you, Mr. Chairman.

Mr. AIKEN. It's one of the more complex problems in aeronautics, and one of our approaches to it is to try to develop predictive systems which will be able to determine the effects of ice accretion on the aerodynamic characteristics of airplanes. We're limited with the 9- by 6-foot tunnel at Lewis at the present time, one of the reasons for AWT, as proposed. And we do have significant flight test activities with a couple of aircraft and some rotorcraft that we work with with the Army. But the program, like many others, could be bigger. But it's just constrained, like everything else.

Mr. BOEHLERT. Thank you.

Dr. Martin, according to Aviation Week, industry is planning to flight test a counterrotating propfan in 1986, which is supposed to have performance advantages over the system NASA is planning to flight test in 1987. Now, does it make sense that, even in the best of times—and these are not the best of times—to spend $42 million on a program that will be developing technology that is less advanced than what industry is developing on its own?

Dr. MARTIN. I would say yes to that, Mr. Boehlert, primarily because the economic potential of advanced turboprops is so huge that one ought to avoid freezing into a given configuration too soon, and that's what would happen if we left it just to industry.

There would be a couple of design points and we'd be frozen, and that's as far as it would go. The program that we have going has a test in 1987, which is single rotating tractor, as a kind of a baseline test from which we can compare all other activities.

The GE unducted fan, which I think you are alluding to, is a part of that program, and the data will be available to NASA and to all the aviation community as a result of that, and will provide much wider dissemination of the information and much more richness of opportunities will come from that than if we just, as I said, froze into a single design configuration at this point.

So I think it's money wisely spent, and I hope you will approve that.

Mr. BOEHLERT. The other question I would like to address is that you show a total of over $72 million in research, which you claim will indirectly benefit general aviation. Could you be more specific and perhaps provide us with a few examples?

Dr. MARTIN. Yes, sir. The $72 million is based on a judgment call, where two or three different informed people in our program office made the judgments and they all came out reasonably close to that. But first of all, it's not an accounting number in the sense that you could audit it and come up with the same number each time.

So with that as a proviso, we found that about $10 million of the advanced turboprop is relevant to high-speed commuter aircraft, roughly $7 million of the numerical aerodynamic simulation facility funding is considered to be directly beneficial to general aviation design processes, $5 million of advanced materials development and failure mechanisms and analytical techniques is also applicable.

Seven million dollars in displays and the interactions between pilot and aircraft in the human factors program is widely applicable. Similarly, a couple of million dollars in ceramics and host.

So those are some examples. Those are some examples, and we could provide for the record a more complete list.

Mr. BOEHLERT. I would appreciate that.

[Material to be supplied follows:]

AERONAUTICS R&T INDIRECTLY APPLICABLE TO
GENERAL AVIATION AND COMMUTER AIRCRAFT
(FY 1986 Congressional Request)

Budget Category Program Area	Resources $,K	Specific Elements
R&T Base Fluid & Thermal Physics	14000	Computational Fluid Dynamics; Viscous Flow Control; Experimental Aerodynamics; Experimental Test Techniques; Wind-Tunnel Operations; University Research Grants
Applied Aerodynamics	5200	Laminar Flow Control; Powered Lift; Flight Dynamics and Controls; Wind-Tunnel Operations
Materials and Structures	4800	Landing Dynamics, Advanced Material Concepts; Life Prediction; Composite Materials; Aeroelasticity; Structures and Dynamics; Engine Materials; Structural Analysis
Propulsion & Power	5500	Small Engine Component Technology; Transmission Research; Instrumentation; Wind Tunnel/Facility Operations
Information Sciences	7600	Concurrent Processing; Reliable Computing; Supercomputing Facilities
Controls & Guidance	4400	Advanced Transport Operating Systems (ATOPS); Guidance and Navigation; Advanced Control Theory and Systems
Human Factors	7200	Flight Management; Human Performance Methods; Simulator Facility Operations; Human Factors Facility Operations; Aviation Safety.
Flight Systems	2200	Aviation Safety - Atmospheric Processes, Severe Storms, Icing; Flight Support; Rotorcraft Icing
Systems Analysis	450	Advanced Systems Studies
Systems Technology Programs High Performance		
- High Performance Flight Research	550	Forward Swept Wing Flight Research Addressing Low-Speed Stability and Control
- Host	1000	Hot Section Prediction and Analysis Techniques; Life Prediction
- Ceramics	1000	Fundamental Material & Manufacturing Process Research
- Oblique Wing	1500	Advanced Concept Flight Research
Advanced Propulsion - Advanced Turboprop	10000	Single- and Counter-Rotation Propeller And Drive System R&T
Numerical Aerodynamic Simulation	7000	National Facility for Computational Aerodynamics, Structures, etc.

Mr. BOEHLERT. One final question—I have two final questions. I asked one of them. Where is the work on the host program carried out?

Dr. MARTIN. It's a mixed bag. There is some done in-house at Lewis. There is some done in universities. And it's the kind of work that, so to speak, you can "buy it by the yard." It's a level-of-effort sort of thing, and you want to keep doing it continually to take advantage of what nature offers you at any given time in the way of improvements. But both in-house and out-of-house.

Mr. BOEHLERT. But what is going to be the effect of the proposed stretchout?

Dr. MARTIN. The payoffs will come a little slower, but they might be a little bit better because more information will accumulate in the meantime. So even at that, it's kind of a tradeoff.

Mr. BOEHLERT. All right. Thank you very much. No further questions.

Mr. GLICKMAN [presiding]. Just a clarification. What I was talking about before with respect to icing, there may have been some failure of communciation. I am talking more of icing research in connection with airplanes on the ground, and I think you were probably talking about more of the work that's done in connection with icing in the air.

Both are important. I just wanted to make sure that you didn't neglect—you know, most of your work is the former, not the latter. And I just wanted to make sure you didn't neglect the latter aspect of the icing problem.

The other thing is, just for the record, your budget proposal for the personnel side reflects a 5-percent pay cut; does it not?

Dr. MARTIN. That's correct.

Mr. GLICKMAN. OK. Well, you realize that's not going to happen. I mean, I am just telling you that.

Dr. MARTIN. Mr. Glickman, I have a boss. [Laughter.]

Mr. GLICKMAN. Yes. OK. All right. That means you probably have to come back for a supplemental at some point in time. I think this is what I call Alice-in-Wonderland budgeting. I realize that you have no control over this, but it's going to wreak havoc on your budget process because it's going perhaps to lead to serious morale problems as you then either have to decide if you get a supplemental or you reduce your work force or a combination of both, or perhaps neither, depending upon what Congress tells you to do. But, you know, you realize we're not going to approve a 5-percent pay cut. A freeze is possible.

In any event, I think that—oh, one final question on general aviation. I notice that you have enhanced your levels of work in general aviation a little bit over last year, at least on the basis of our staff numbers.

Dr. MARTIN. Well, that's right, and I think there has been an attitude change as well. When I was before you last year, I promised to get acquainted, and I did. In fact, I got my aviation tie out today—general aviation tie.

Mr. GLICKMAN. I see that. I have the same tie. [Laughter.]

OK. Well, you know, the industry is in trouble from a financial point of view, but I am just pleased to see that you have some increase in allocation for it.

Dr. MARTIN. I think two things are changing. One, the funding level is increasing modestly. But I said there was an attitude change; I think the people in the general aviation community know that we're interested, that we're available to talk to, and that if they have an ax to grind, we want to help them do it. And so I think there are changes, and it will continue.

Mr. GLICKMAN. I want to thank you for your testimony. I thank Dr. Colladay for coming, as well. I would tell you that as far as I can see, although we will look at the recommendations of the advisory committee, I don't think that the aggregate numbers will be changed very much, the top number. We may make some changes inside.

The only thing I could see happening is that this Congress passes some sort of a budget freeze; then whatever increase you have over last year—which is not significant but——

Dr. MARTIN. Two percent.

Mr. GLICKMAN [continuing]. You know, might be reduced to $10 million or however else you do it. And that would be from a public policy change. The only thing I could really see happening in aggregate numbers, which we don't know right now what we're going to do.

But I want to thank you for working with us as well as with the Advisory Committee, and for your excellent job in running the aeronautics programs.

Dr. MARTIN. It has been a pleasure to work with your staff and the committee, and we look forward to responding to the opportunity that you offered.

Mr. GLICKMAN. All right. Thank you.

We now have a rollcall, which is probably a good time to have one because I think this may be the last one today, hopefully. So our next witness is Harvey Album, in connection with the Advisory Committee on Aeronautics. We will be back in about 15 minutes.

[Recess.]

[The prepared statement of Dr. Martin follows:]

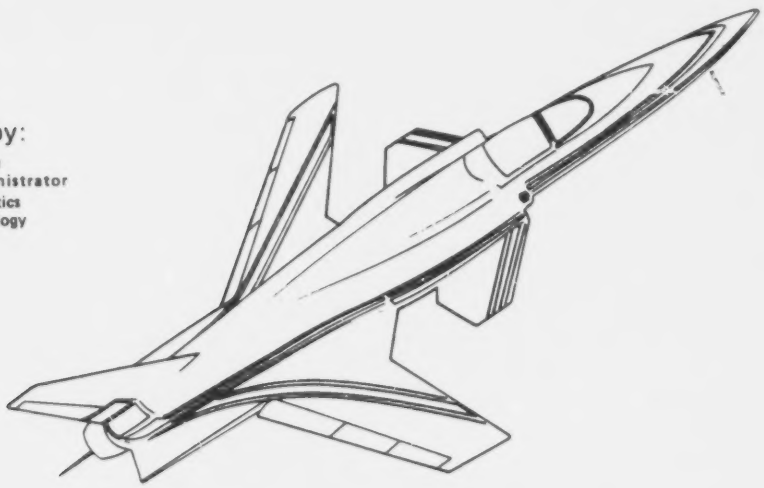
NASA
National Aeronautics and Space Administration

Hold for Release Until
Presented by Witness

March 5, 1985

Subcommittee on Transportation, Aviation and Materials
Committee on Science and Technology

House of Representatives



Statement by:
Dr. John Martin
Associate Administrator
Office of Aeronautics
and Space Technology

99th Congress

HOLD FOR RELEASE UNTIL
PRESENTED BY WITNESS
MARCH 5, 1985

STATEMENT

OF

Dr. John Martin
Associate Administrator for
Aeronautics and Space Technology

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Transportation, Aviation
and Materials
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee:

I am pleased to present to you today NASA's FY 1986 Aeronautical Research and Technology (R&T) budget request. I believe that the proposed program meets your desires for a balanced effort in both disciplinary and systems activities within the constraints of the overall Federal budget. This program will allow NASA to maintain the outstanding aeronautical R&T capabilities represented by the Ames, Langley and Lewis Research Centers as well as to enhance the nation's vital technology base through high leverage research in the traditional disciplines and in systems research areas such as advanced turboprop technology and numerical aerodynamic simulation. The overall thrust of our program is to advance those aeronautical technologies which are critical to continued preeminence of U.S. military and civil aviation. It is important to note that most of NASA's aeronautical research has common applicability to both military and civil aircraft.

As some members are new to this Subcommittee, I would like to begin by describing several important examples of aeronautical technology advancement where the contributions made by NASA were central and which also illustrate the lengthy technology development time spans involved from first principles to proof-of-concept to application. The four technical areas chosen are supercritical aerodynamics, tilt rotor technology, propulsive lift and energy efficient propulsion.

As illustrated in Figure 1, NASA conducted extensive research on the aerodynamic characteristics of airfoils in the period from 1962-1974, developing the initial concept and a family of supercritical airfoils to minimize the large increase in drag which occurs at transonic

speeds. Drag reductions of 15 to 20% are now possible, enabling aircraft of lower weight and increased cruise speed or in the case of fighter aircraft, increased maneuverabilty. This Langley invention, conceived and patented by Richard Whitcomb, who received the Collier Trophy for it in 1954, has begun to find its way into wings recently designed for the Boeing 767 and the McDonnell Douglas F-18 aircraft. However, prior to acceptance as a proven technology it was necessary to conduct extensive flight research. Two of these programs, the NASA F-8/Supercritical Wing with a transport type wing and the joint NASA/Air Force Transonic Aircraft Technology (TACT) F-111 variable sweep fighter wing configuration are illustrated in the center of Figure 1.

A second major breakthrough was in rotorcraft technology, as illustrated in Figure 2. Tilt rotor aircraft operate as helicopters at low speeds and as fixed wing propeller driven aircraft at higher speeds. This permits vertical take-off and landing, longer cruising range, and speeds up to 400 mph (as compared to current helicopters which are limited to less than 200 mph). Concepts for tilt rotor vertical take-off and landing (VTOL) aircraft were studied in the late 1940's. During the 1950's, the XV-3 wind tunnel and flight programs investigated the feasibility of the tilt rotor concept at low speed and identified the key technology issues. Subsequent research, including the testing of flightworthy rotor systems at small and large scale, verified potential solutions to the basic rotor/pylon/wing dynamic stability problems evident in the XV-3. In the early 1970's, the joint NASA/Army XV-15 Tilt Rotor Research Aircraft program was launched. By the early 1980's, the two proof-of-concept research aircraft and other supporting research had proven that the critical design issues could be successfully addressed. This provided the confidence level necessary for DOD to initiate full scale engineering development of the Joint Services Advanced Vertical Lift Aircraft (JVX) leading to production of over 500 aircraft with an initial operational capability (IOC) in the early 1990's. Numerous civil applications of this technology are expected to fcllow the JVX development.

The next example depicts a much sought after goal in aeronautics, the ability to significantly decrease the take-off and landing distances for large heavily-loaded aircraft. The payoffs are enormous for both civil and military aircraft in terms of much shorter runways, enhanced basing flexibility, and increased climbout and descent trajectories which minimize community noise or exposure to ground fire. Two innovative concepts have been explored over the past twenty five years, originating with wind tunnel experiments (Figure 3) at Langley in the late 1950's. These concepts are the externally blown flap in which wing lift is increased by using the jet exhaust impinging on an extended wing flap system,

and the upper surface blown flap where lift is augmented by inducing high velocity airflow (supercirculation) over the wing upper surface with the jet exhaust. The Air Force applied these separate principles to two prototype aircraft, the Boeing YC-14 and the McDonnell Douglas YC-15 in the late 1970's. NASA developed the Quiet Short-Haul Research Aircraft (QSRA), a four engine upper surface blown flap airplane which is still being used, to study the handling and control qualities of this class of aircraft. It is interesting to note that the QSRA has made carrier landings in cooperation with the U.S. Navy and is the largest and heaviest aircraft ever successfully landed on a carrier without arresting gear. At the present time the externally blown flap concept is being incorporated in the Air Force C-17 scheduled for initial operational capability in 1987.

The final example of the evolution of NASA technology through the application phase is energy efficient propulsion technology, illustrated in Figure 4. NASA research in the 1960's on transonic compressor aerodynamics and turbine film cooling provided the basis for revolutionary advances in propulsion system efficiency. The NASA Energy Efficient Engine (E^3) program (1979-1983), conducted with General Electric and Pratt & Whitney, advanced the state-of-the-art in key component areas. At the conclusion of the E^3 program, the components were integrated to evaluate performance, structures, and engine dynamics at the systems level. Today these technologies provide over a 15% increase in turbofan fuel efficiency over contemporary designs and are being applied in the world's most advanced engines, the Pratt and Whitney PWA-2037 and the General Electric CF6-80C.

As these examples illustrate, it takes many years (often over a decade) from first principle to product application of aeronautics technology. This process usually requires verification of technology effectiveness either in flight or in large scale systems tests which is best accomplished through government and industry cooperation.

With this as background, I'd like to discuss the details of NASA's FY 1986 budget request and some recent changes in Headquarters management. In order to more effectively manage the complex and interrelated elements of our aeronautics R&T programs and to more closely align Headquarters management with our Research Centers, I have reorganized the Office of Aeronautics and Space Technology (OAST). Figure 5 shows the new OAST management structure which was approved by Mr. Beggs in August, 1984. To provide the necessary centralized planning, budget allocation, and vehicle class program integration we have established the Offices of Director for Aeronautics, Director for Space and Director for Institutions. The detailed technical direction, oversight and

reporting functions for both aeronautics and space technology programs are handled by the technical divisions. The Research Centers, Ames, Langley, and Lewis are responsible for implementation of the approved programs. They report directly to the Associate Administrator for Aeronautics and Space Technology.

The FY 1986 NASA Aeronautics R&D budget request is shown in Figure 6 compared with previous years' budgets. The total request for FY 1986 is $354.0M. The Systems Technology line reflects an overall decrease. This is due primarily to the termination of the Advanced Composite Structures Technology program and a stretchout of the Hot Section Technology program. Funding for the Advanced Turboprop and Oblique Wing programs has been increased. Further details of the budget have been provided in material submitted previously to the Subcommittee. I'll summarize the key elements for you today.

Figure 7 shows the distribution of the $354.0M R&D funding by performer and by Center, and also indicates the estimated division of aeronautics manpower (3561) among the Centers. As you can see, these resources are about evenly distributed among the three Research Centers. A breakdown of the R&T Base and the Systems Technology elements of the FY 1986 R&D budget request is shown in Figure 8.

The applicability of disciplinary research to various specific classes of aircraft is a way to view the NASA budget as perceived by the various sectors of the aviation community. Such an analysis of the proposed program for FY 1986 is shown in Figure 9. In the upper portion of the chart labelled DIRECT, the R&T Base and Systems Technology resources are divided into General Aviation, Transport, High Performance, Rotorcraft, and Generic categories. As indicated, for example, $11.1M of NASA aeronautical research is directly applicable to General Aviation aircraft and $52.0M of the $354.0M total is directly applicable to Rotorcraft. However, it is important to recognize that there are additional indirect benefits to these vehicle classes from Generic research or from research directly applicable to other vehicle classes. The lower portion of Figure 9 labelled INDIRECT quantifies these additional synergistic benefits that for General Aviation (as an example) are equivalent to an additional $72.4M of research.

NASA AERONAUTICAL RESEARCH FACILITIES

In addition to experienced researchers and funding to support their activities, an integral and enabling component of NASA's aeronautical research and technology program is the agency's research facilities. They are national assets considered by industry to be central to

the future development of superior U.S. military and civil aircraft.

Examples of major new facility capabilities are shown in Figure 10: (1) the National Transonic Facility (NTF) has demonstrated performance capability over its entire operating envelope, and research testing is beginning; (2) the 40x80x120 foot Low-Speed Wind Tunnel is planned to have its 40x80 foot circuit in operation in the spring of 1986 and the 80x120 foot test section in operation by late 1987; and (3) the Numerical Aerodynamic Simulation (NAS) Facility which you will hear more about shortly.

Now, I plan to describe the key elements of the Aeronautics R&T Base and Systems Technology programs emphasizing recent accomplishments and/or directions for continuation in FY 1986.

Aerodynamics

The aerodynamics research and technology programs provide the computational methods and experimental data base required to develop advanced aerodynamic concepts and configurations for future civil and military aircraft. Support is also provided for the operation of a complex of wind tunnels and computational facilities which supply vital capabilities for use by the entire U.S. aeronautics community.

The Numerical Aerodynamic Simulation (NAS) Program, which will provide the most advanced computational system in the world for aeronautical research and development, is a centerpiece of the Agency's Aeronautics program. The NAS capabilities will enable maintenance of U.S. leadership in the aeronautical sciences by providing a pathfinder tool for the development of new, advanced analysis and predictive techniques for aerodynamics research, preliminary aircraft concept developments, and configuration/-design refinement. These capabilities will also enable the expansion of knowledge in the fundamental physics of other computationally intensive disciplines, such as, chemistry, structures, materials, weather and climate.

NAS full scale development efforts (Figure 11) began in FY 1984, and rapid progress has been made. Major procurements have been awarded for High Speed Processor Number One (HSP-1/Cray 2 supercomputer), Systems Test and Integration, Systems Software Developments, Integrated Support Processor Complex (ISPC), and workstations. On the technical front, a network testbed was developed and used to test networking hardware and software. A Cray XMP-1/2 computer was acquired and configured to simulate the Cray 2 uniprocessor, permitting initiation of full scale system software development. The initial NAS workstations have already been delivered, installed, and

are undergoing checkout by computational aerodynamics researchers.

The Long Haul Communications System (LHCS) will undergo a user test beginning in late FY 1985. In FY 1986, workstations will be placed at remote sites and networked to the NAS testbed via land lines and satellite links. With the delivery of the Cray 2 supercomputer in September 1985, the NAS will have all the major pieces of its initial system in place and intense test and integration activities will begin. The primary objective for FY 1986 is to activate the Interim Initial Operating Configuration (IOC) in July of 1986. It will feature high-speed processing networks with work stations, graphics capabilities, and long-haul satellite and land-line communication links between Research Centers. At that time, the NAS capabilities will be the most advanced in the world, providing 256 million words of memory and a sustained operating speed of at least 250 million floating point operations per second (MFLOPS). The IOC will provide the user community full on-site and limited off-site access to the NAS capabilities. Following the test of the long haul communications system, the LHCS systems should be upgraded to provide nationwide access to the NAS system. Procurement activities should be initiated to acquire the second High Speed Processor (HSP-2) and to complete development of the major NAS subsystems. These procurements should be timed so that delivery will occur after completion of the NAS Facility in early FY 1987.

Computational fluid dynamics is emerging as an essential and powerful tool for improved understanding of both external (aircraft) and internal (propulsion system) flow physics. It provides the capability to simulate conditions and flow phenomena which are difficult to measure physically. These results can be readily visualized and manipulated to support detailed analyses and design trades. This technology continues to progress steadily from the capability to simulate simple flows over basic component shapes to the more important capability to calculate real flows over complete aircraft and through the internal passages of turbine engines. Recent accomplishments include the first solution of a highly complex, time evolving viscous dominated flow about a deployed aircraft wing spoiler shown on the upper left of Figure 12. A 3-dimensional code incorporating shock/-boundary layer interactions and other complex flow effects, has also been developed to evaluate the performance of hypersonic inlet geometries. Flow calculations about complete aircraft configurations, based on less sophisticated inviscid, full potential flow codes have been performed. This capability has already been used to redesign wings on commuter and general aviation aircraft and in the design of transport aircraft. The goal for FY 1986 is to analyze complex flows (viscous effects) for full aircraft and engine configurations

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operating over realistic flight conditions, as illustrated on the right of Figure 12. The Numerical Aerodynamic Simulation (NAS) program will enable us to simulate real gas effects and flows for entry and hypersonic cruise and manuever vehicles, pursue direct simulations of transition and turbulent flows, and obtain insights into the fundamental mechanisms of turbulence generation. Advanced computational aerodynamics design tools will permit preliminary design developments for aircraft and engines which are much closer to final configurations than are currently possible, resulting in greater economy in wind tunnel and test rig activities while producing superior products.

Reducing the viscous drag caused by skin friction is a key objective in aerodynamics research since it accounts for roughly one-half of an aircraft's total drag. Three techniques are being explored (Figure 13) that offer the potential for significant fuel savings: (1) natural laminar flow (NLF) airfoils designed so that favorable pressure gradients exist over extensive portions of the airfoil to assure laminar flow, (2) laminar flow control (LFC) where suction near the wing leading edge is employed to maintain low-drag laminar flow, and (3) advanced concepts to reduce turbulent drag on fuselages where laminar flow is difficult to achieve. Recent NASA research results indicate that significant amounts of laminar flow may be obtained on the wing surfaces of small commercial transports having moderate sweep angles with either natural laminar flow or a combination of NLF and LFC. An F-14 aircraft with variable wing sweep capability will be flown in FY 1986 with a number of NLF wing gloves of differing contours to study the effects of sweep angle and the conditions under which transition from low drag natural laminar flow to higher drag turbulent flow will occur. The laminar flow control tests on the Lockheed JetStar aircraft will be completed in FY 1986 with the testing of the Lockheed and Douglas wing leading edge concepts under representative flight conditions at various locations in the United States. The successful demonstration of reliable, maintainable laminar flow over the leading edges will be an important milestone in aircraft engineering. These tests, together with the continuing research on new materials and fabrication methods, analytical methods, and design techniques, will bring laminar flow technology closer to practical systems that can be considered a realistic design option for future transport aircraft. In the area of turbulent drag reduction, industry flight tests have confirmed that one of the NASA-developed concepts, "riblets", can provide net turbulent drag reductions of approximately six percent. Hydrodynamic tests have also shown that riblets are effective for certain naval applications. An alternative turbulent drag reduction approach, large eddy breakup (LEBU) devices, will also be pursued in FY 1986 in wind tunnel and flight tests and

experiments will be conducted on LEBU's in combination with riblets. Further net drag reduction will be sought through optimization of the miniature airfoils used in the LEBU device itself.

The advanced configuration aerodynamics activities build on current research in aeronautical disciplines by investigating advanced aircraft configurations that integrate multiple levels of new technology to see how these emerging technologies interreact. Figure 14 shows wind tunnel models of advanced aircraft where a total systems approach is being used to maximize component integration benefits. The objectives of these activities are to develop improved procedures and design data for conventional and unconventional aircraft configurations and to develop techniques for aerodynamic configuration assessment. During FY 1984, wind tunnel tests were conducted on various commuter design configurations which showed the potential performance benefits of over-the-wing propeller installations and the relative benefits of aft-mounted engine designs from stability and control considerations. Initial design studies of a natural laminar flow (NLF) fuselage were also completed. The FY 1986 program will concentrate on applying NLF aerodynamics, viscous drag reduction concepts, turboprop propulsion, and active flight controls to advanced configurations for commuter aircraft.

The objectives of helicopter configuration research is to integrate the technology advances in aeroacoustics, aeromechanics and materials with operational requirements, such as a mast-mounted sight, and to utilize new analysis and test techniques. In general, higher performance and reductions in noise and vibration are the key future design drivers. During FY 1984, an advanced rotor system and mast-mounted sight were tested, the first small-scale tests of rotor/fuselage interference were conducted, and it was demonstrated that advanced tilt rotor blades improved hover performance. During FY 1986, full-scale tests of main rotor/tail rotor/fuselage interference will be conducted, advanced tilt rotor blades will be flight tested, the first comprehensive rotor noise prediction analysis will be made, and NASA will support the testing of the Joint Services Vertical Lift Aircraft (JVX) and light scout/attack/utility helicopter (LHX).

Aerodynamic configuration integration is also a key technology for supersonic short take-off and vertical landing (STOVL) and hypersonic cruise aircraft. Advanced configurations of these vehicle types being tested are illustrated on the lower left and upper right of Figure 14.

Materials and Structures

The research and technology program in materials and structures provides the foundation for advances in new and improved materials, structural concepts and analytical methods. The major goal for advanced structural materials is to achieve increased durability through improved fatigue and fracture resistance, damage tolerance and high temperature capability. This requires fundamental understanding of material processes and material constitutive behavior. The advances in material technology will provide the basis to exploit improved material properties including increased strength to weight capability and higher stiffness for new structural concepts needed for the very demanding flight environments projected for future aircraft structures. This will require a greater reliance on efficient and accurate structural analysis capability during the vehicle design process. A major goal in structures technology is to develop new and improved analytical methods to understand complex structural behavior of new design concepts employing advanced materials and to predict their performance.

Lightweight structural concepts and advanced analytical technologies represent key areas for future high speed aircraft. To meet this need, the current program is developing imaginative design concepts for hot structures operating at up to 1800°F. It is essential that these structures be extremely lightweight for greater aircraft range and still be able to maintain their strength and precise design shape under high thermal loads. One promising concept under investigation (Figure 15) is the use of load carrying honeycomb panels of high temperature nickel base superalloys. Superalloys inherently possess the capability for long life at high temperatures and are used extensively throughout the combustor and turbine sections of modern high performance jet engines. The development of structural panels for hypersonic vehicles represents a challenging application. During the past year a twenty panel array of this superalloy honeycomb material was tested in the Langley High Temperature Tunnel under hypersonic conditions. The structure withstood local temperatures of up to 1850°F. Concurrent with this test, a comprehensive analysis of fluid flow over the panel accurately predicted vortex induced- and impingement-heating effects leading to local hot spots and thermal bowing. A complex curved superalloy honeycomb test panel shown in Figure 15 has now been fabricated and will be tested. Further work on aerothermal load prediction capability will also continue during the coming year.

In FY 1986, the aeroelastic behavior of aircraft will continue to be an area of NASA research emphasis. This technology involves the study of the complex interaction

between air loads and a flexible structural member, such as an aircraft wing, a rotorcraft blade, or a weapon carried on a wing pylon. Flutter is a major concern. Examples of several advanced concepts for flutter suppression and control are illustrated in Figure 16. A passive approach to flutter alleviation has been applied to the difficult problem of wing/store flutter in military aircraft. Frequently, external stores such as missiles or bombs are added to the inventory of an aircraft long after it has been designed causing new aeroelastic instabilites. A new concept called a decoupler pylon recently was flown on an F16 and successfully isolated the dynamic response of the wing from the inertial forces of the missile. A 40% increase in aircraft speed was achieved before the onset of flutter versus the standard pylon configuration. In the past year, a semispan model of a four engine transport with winglets was tested in the unique Transonic Dynamics Tunnel (TDT) at Langley Research Center. Flutter boundary data, experimentally acquired in the tunnel at transonic Mach numbers, was consistent with flutter speeds previously predicted by theory. New transonic analytical methods which include viscosity effects will be developed in the coming year to further advance aircraft flutter prediction capability. As part of the Army/NASA/Industry program to develop the Joint Advanced Vertical Lift (JVX) Aircraft, a semispan model with a wing-tip mounted tilting engine and rotor was tested in the TDT. Wing/rotor aeroelastic stability in the aircraft mode of operation was measured. The rotor was then tilted for dynamic loads measurement during conversion and in the helicopter mode. The data acquired will result in JVX modifications to increase flutter boundaries and will provide a data base for advanced analytical methods development.

The trend in modern aircraft gas turbine engines is toward increased performance and efficiency. Inside the engine this translates to higher temperatures and pressures which in turn lead to increased maintenance cost and decreased engine life. To overcome these problems Lewis Research Center has been pursuing a focused research program to advance the technology which will lead to engines with a high degree of durability and a long service life. Research results are being picked up by the propulsion industry at a rapid rate. Key aspects of this Hot Section Technology (HOST) program are shown in Figure 17. This program has been extended into FY 1989 with a resulting $4.1M reduction from planned FY 1986 levels due to priority decisions in the budget process. During the past year significant gains were made in developing an accurate and reliable probe which can measure large rapid temperature fluctuations in an acutal engine. Tests using this probe have found rapidly occurring, random thermal spiking of up to 1000°F in the hot section of an engine. Improvements are being made to

further increase the performance and accuracy of this probe. Concurrent with advances in instrumentation were the developments of highly advanced computer codes to predict the detailed temperature environment and associated stresses in turbine engine hot section components. Specifically, a new capability was developed to predict the complicated turbine blade heat transfer process including the effects of cooling air which is ejected from the body of the blade through a "shower head" of minute cooling holes along the leading edge. Coupled with this improved thermal analysis technique, new structural analysis methods have been developed which can calculate the complex stress conditions in engine components more accurately and efficiently than before. Considerable research is also being performed to identify material failure modes which can limit longer engine life. During the past year critical failure modes for turbine blades were identified under complex loading conditions including the environmental effects of varying temperatures and the structural effects of repeated loading and unloading (fatigue) and the slow steady deformation that occurs at high temperature (creep).

The performance, durability and costs associated with U.S. aircraft gas turbine engines are dependent on the materials available for critical hot-section components. Use of ceramic materials in gas turbine engines offers the potential of higher temperatures, lower cost, greater corrosion resistance and the added benefit of containing no strategic materials. However, they are inherently brittle materials and impose unique technology needs in order to realize their full benefit. Some of the recent NASA advances in ceramics are shown in Figure 18. An advanced 3D structural analysis capability was developed to predict the probability of failure in geometrically complex engine components. As all ceramic structures contain a distribution of microscopic cracks which control the strength and life of the component, sophisticated statistical methods must be used to calculate the likelihood of failure. This newly developed analysis capability will enable a clearer understanding of failure modes and the development of design methodologies which can reduce the component sensitivity to these modes. An extensive effort is on-going to develop better sintering processes by which components are formed and to optimize the additives that are used in this process to enhance the material microstructure. During the past year significant advances were made in both of these areas. Silicon carbide when sintered by a new process demonstrated a 60% increase in bending strength. In the case of silicon nitride, a new nitrogen sintering process with selective additive contents demonstrated the potential for improved structural performance at high temperatures. Efforts to improve the properties of ceramics through additives and processing will continue this year and the scope expanded to include ceramic composite materials. A

further application of ceramics is for coatings on metal blades to protect them against the very high temperatures and corrosive nature of the combustion products. During the past year a coating was developed which independently survived 3000 thermal cycles and 300 hours of continuous exposure to 2500°F exhaust gas temperatures. Current directions are to refine overall coating performances under more complex loading conditions and to further improve the methods of applying protective ceramic coatings.

In FY 1984 NASA initiated a cooperative program with industry in advanced composite structures technology which includes the development of improved materials and critical elements for the design of large heavily loaded aircraft wings and fuselages. Preliminary designs have been developed which save up to 30 percent of the weight of conventional metal wing and fuselage structures, and critical design issues have been identified. This effort has developed highly loaded composite panels that can satisfactorily meet damage tolerance criteria and continue to support design loads after impact damage. Lightning strike tests have further indicated that stiffened composite panels with mechanical fasteners can be designed to eliminate the danger of electrical spark arcing that could cause aircraft fuel tank explosions. Additionally, special laminate treatments to prevent fuel leakage have also been shown to be effective. Concepts for highly loaded critical wing-fuselage joint assembles have the ability to carry loads and meet fatigue criteria. In FY 1986, the Advanced Composite Structures Technology program will be terminated. NASA investment of approximately $160M in composite structures technology has provided a base which industry can now apply to new products. NASA will continue to pursue fundamental composite materials and structural concepts research in the R&T base.

Propulsion

Current propulsion research thrusts encompass a wide range of technologies that promise new or more effective propulsion research tools, engine components, or system capabilities.

Propulsion instrumentation is an important enabling technology for fundamental propulsion research. In addition to more traditional areas in instrumentation research, NASA activities include high temperature electronics and sensor technology for advanced propulsion control and diagnostics systems. In FY 1986, emphasis will continue on non-intrusive and minimally-intrusive measurement systems (Figure 19) such as laser doppler velocimeters, color schlieren, and thin-film sensors which provide detailed information on flow fields and mechanical loads with little or no affect on the

characteristics being measured. High temperature electronics research will continue to concentrate on silicon carbide based electronics, which have the potential for operation at temperatures as high as 1000°F. The use of fiber-optics in advanced sensors and for data transmission in advanced engine control systems will be investigated in a joint Department of Defense/NASA study.

In 1983, General Dynamics constructed a 1/2 scale, semi-span model of the E-7 Short Take-off and Vertical Landing (STOVL) aircraft, which was tested in the NASA Lewis Research Center 9X15-foot wind tunnel as shown in Figure 20. The objective was to assess the performance of the ejector used to provide vertical lift at low-speed flight. The working principle of the ejector is schematically represented in the figure. Results indicated that the ejector concept worked well, hence, the model was converted by to a full span configuration and tested at General Dynamics and in the NASA Langley Research Center, 4X7-meter wind tunnel. The data from various, separate tests, shown in Figure 20, indicate consistent performance trends. Current plans are to test, in early spring of 1985, a powered 1/6 scale free- flight model of the E-7 aircraft in the NASA Langley Research Center 30x60-foot wind tunnel to determine the optimal control laws and power requirements for safe manned operation. Further plans include the design, fabrication and testing of a full-scale engine-powered model to determine the performance of the ducting system which feeds engine air to the ejectors. These tests are essential to validate the complete concept prior to consideration of a flight test program.

NASA intermittent combustion (I.C.) engine research, illustrated in Figure 21, encompasses both in-house and contractor efforts. During the past year, these study and research activities prompted NASA to concentrate research for advanced General Aviation power plants on the rotary engine. Its performance, installability, and multi-fuel capability, along with other advantages, make it an outstanding candidate propulsion system for light aircraft and other related applications in the early 1990's. During 1984, under contract with John Deere, a rotary engine research rig was successfully operated on jet fuel using stratified charge (two stage) combustion. Studies of a ceramic rotor concept were also completed showing the feasibility of this efficiency enhancing innovation. A follow-on contract with Deere will exploit the new Stratified Charge Rotary Engine (SCRE) rig. The component analyses will be extended to include the stationary housings, thereby defining an overall thermal model of the adiabatic (low heat rejection) SCRE. Wear strip testing of ceramic seals will be initiated and advanced turbocharger technology adapted. A major new internal airflow computer code will be validated by laser optic measurements in a transparent rotary engine rig.

Small turbine engines are very important to many types of aircraft including general aviation, commuters, helicopters, and cruise missiles and to many ground applications. Current small engine efficiencies are 8 to 10% less than large engines. Further, the design techniques for large engine components are inadequate for accurately predicting the performance of small components. Axial flow compressors of the type used in large gas turbine engines exhibit sizeable efficiency losses at the smaller sizes as illustrated in Figure 22. This loss can be reduced in small engines by substituting centrifugal compressors. However, centrifugal compressor passages involve much more complex flow phenomena. Experimental research has revealed unpredicted centrifugal compressor flows that exhibit high turbulence, strong secondary flow disturbances, and separation as shown in the lower half of Figure 22. These flow anomalies cause performance penalties in all centrifugal compressor sizes. The elimination or reduction of these loss generators offers the potential for highly efficient centrifugal compressors that would approach the excellent, recently demonstrated Energy Efficient Engine axial flow compressor efficiency. At this level of centrifugal compressor efficiency, the prospect of high performance, small centrifugal compressor engines rivaling the large engines can be visualized. Future research activity will utilize the very large, low-speed centrifugal compressor pictured at the upper right of Figure 22. The large size will permit detailed measurements of the previously noted centrifugal flow anomalies as key compressor dimensions and parameters are changed. Accurate determination of these secondary flows will permit more representative, analytical modeling of internal centrifugal compressor flow. This will enable designers to minimize the undesirable flow phenomena and the performance losses they cause.

Advanced turboprop technology offers the potential for a 20-30 percent reduction in aircraft fuel consumption while maintaining the jet speed and cabin environment of modern turbofan powered aircraft. All elements of the NASA Advanced Turboprop (ATP) program are now in place (Figure 23) to achieve technology readiness for both single- and counter-rotation propellers, drive systems, and aircraft installations in the late 1980's. Major new activities initiated in FY 1984 include a proof-of-concept test of the General Electric Unducted Fan (a gearless, counter-rotation propulsion system), the Propfan Test Assessment (PTA) program under contract with Lockheed-Georgia to flight test a 9 foot diameter single-rotation propeller in 1987, and largescale gearbox technology programs with Pratt and Whitney and the Detroit Diesel Allison Division of General Motors. Some recent accomplishments include a stability and control evaluation of aft-mounted turboprop models at the Langley Research Center, completion by Hamilton Standard of the

large-scale blade design, initial performance testing of counter-rotation propeller models representing both geared and gearless concepts, measurement of noise patterns for single- and counter-rotation propellers, and evaluation of turboprop inlet pressure losses and distortion.

As shown in Figure 24, several key ATP milestones will be achieved during FY 1986. As part of the flight test preparations, the Large-scale Advanced Propeller (LAP) tests will be completed and the propeller assemblies delivered for flight testing. The flight propulsion system will then undergo ground tests, and a one-ninth scale powered model of the PTA aircraft (modified Gulfstream II) will complete stability and control wind tunnel tests. Low-speed wind tunnel tests will also be performed in the 40X80-foot tunnel at the Ames Research Center on a full-scale test vehicle representing the PTA aircraft for evaluation of air-borne and structure- borne noise. Large-scale research efforts will also include completion of the Unducted Fan concept evaluation. Supporting research will continue to be focused on installation aerodynamics, gearbox technology, propeller source noise, and cabin noise and vibration.

I'll review our hypersonic propulsion research program later in my testimony.

Controls and Guidance

The controls and guidance program is providing the technology for improved civil and military aircraft operations under adverse weather conditions and exploiting new concepts and hardware to increase the efficiency, effectiveness and safety of new airplanes and rotorcraft.

Last year significant progress was made in the development of a technology base for the design, validation and assessment of flight crucial control systems. The results of this research on software and architectural solutions to the critical reliability problem of flight crucial digital control systems are finding immediate applications in major DOD and NASA aircraft programs. One concept for providing protection from software errors, called Resident Backup Software (REBUS), was demonstrated successfully during flight tests using the NASA F-8 Digital Fly-by-Wire Research Aircraft. The concept has been adopted by two major programs, the DARPA/NASA X-Wing and the Air Force F-16C/D, and should result in considerable savings by eliminating the need for independent backup hardware in the flight control systems. Also occurring in 1984 was the transfer to industry of the latest version of an analytical reliability model and its associated computer program, called Computer-Aided Reliability Estimation, Third Generation

(CARE III). It will be valuable in accurately assessing the reliability of ultrareliable control systems expected in future civil and military aircraft that cannot be experimentally verified. Research will continue in the Advanced Information Processing System (AIPS) program to develop and evaluate a new flight computing system architecture. The major technical challenge is to provide the information processing capability to handle the complex control requirements of future aircraft while retaining high degrees of reliability and fault tolerance. The system architecture must also maintain the flexibility to accommodate rapidly evolving component technology. A proof-of-concept hardware/software implementation, will be tested in the Avionics Integration Research Laboratory (AIRLAB) to validate its operation.

The extensive delays experienced at major hub airports in the United States continues to demonstrate the need for research on advanced aircraft system concepts and operating techniques to further efficient use of the Nation's airspace and to maximize the takeoff/landing capacity of our major airports (Figure 25). NASA, in close cooperation with the Federal Aviation Administration (FAA), has been working on this problem for many years, concentrating primarily on airborne system improvements under our Advanced Transport Operating Systems (ATOPS) program. This effort complements the FAA's National Airspace System program involving improvements to the ground-based air traffic control system. Over the past three years, the B-737 research aircraft and simulators used in our ATOPS program have been refitted with reliable state-of-the-art equipment in order to expand the research on airplane systems that interface with the air traffic control system. The airplane is now flying with new and greatly improved computers, and will be fitted with a new research flight deck incorporating advanced, second generation displays later this year. Research will concentrate on better flight path management systems and 4D guidance for optimum aircraft integration with the air traffic control system.

Human Factors

The role of the pilot is changing from that of aircraft attitude controller to that of cockpit systems manager as automated features are introduced to modern cockpits. However, as the technologies of artificial intelligence, large electronic flat-panel displays, and advanced data input methods (e.g. voice recognition, touch panel, eye-mouse, etc.) are incorporated into the cockpit, the crew's role will change again to an even higher level of supervisory control. NASA's Human Factors program is aimed at facilitating this transition to "glass cockpits" and "electronic crewmembers" by developing a knowledge base of aircrew capabilities, limitations and tendencies

in interacting with these systems, which can enable their implementation in a safe and efficient manner.

The Man-Vehicle Systems Research Facility (Figure 26) contains simulators which are used to study pilot supervisory control of aircraft automation, the interactions between the crew and advanced computers, human-matched displays and measures of cognitive workload. The studies include the use of a present day 727 cockpit simulator to establish baselines, illustrated in the lower left of Figure 26, and will progress to the use of the advanced cockpit simulator shown in the upper right.

Another research thrust is to determine the effects of circadian desynchronosis (jet lag) on crew performance. Figure 27 illustrates the airline routes which are being used in various phases of the study. A central hypothesis is that the effect of fatigue is primarily on cognitive and interpersonal behaviors which will constitute an even higher proportion of crew workload in highly automated cockpits. The short-haul phase of the program has been completed and the long-haul phase is about to begin. This program has generated a great deal of interest and support. The U.S. Army and the U.S. Air Force have sent full-time researchers to participate, and the Royal Norwegian Air Force and airlines from Japan and Germany have participated. The final phase of the program will be the development of counter measures to the effects of fatigue and circadian desynchronosis.

Information Sciences

Our research in computer science is focused on the critical aerospace topics of concurrent processing, reliable computing, software engineering, and information management. As you may recall, this is a relatively new R&T program for NASA, initiated by the Office of Aeronautics and Space Technology (OAST) in 1983. We are particularly proud of the success that the Research Institute for Advanced Computer Science (RIACS) at Ames has had in the year and a half of its existence. The professional staff has focused its core research activities on the long-term goal of demonstrating a prototype of a family of computing systems which can support aerospace research from problem formulation to results dissemination. This program of fundamental research is augmented by an active set of focused applied research tasks which address specific problems of immediate relevance to the Ames scientific community. Through RIACS, for example, a model of the Numerical Aerodynamic Simulation supercomputer facility was constructed. Studies of throughput and response time were then conducted to verify the system design. RIACS has already established itself as a notable member of the national research community and is proving itself to be an effective means for

cooperation among government, industry, and academic laboratories.

In our research on software reliability, the Langley Research Center has been experimentally testing traditional reliability models against data collected in AIRLAB. The initial results from this work suggest that generally accepted models for software time-to-failure have serious deficiencies. Work will be continuing over the next year to confirm these results and develop more effective models of software failure phenomena. In information management, graphics research is being conducted which will lead to a general purpose image processing system capable of supporting multidisciplinary aeronautical research. The long term objective is to make 3-dimensional raster graphic images a routine display capability for the non-computer specialist. These types of displays are important for visualizing flows over complex aerodynamic vehicles, for example, and for analyzing the dynamic behavior of large structures under loads.

An important element of the information science program is the provision of high performance computing facilities for aeronautics researchers at Ames Research Center. These include their CDC Cyber 205 and Cray XMP supercomputers, which are vital to national research programs in computational fluid dynamics and ccmputational chemistry. Over the next year, a large central data storage system will be added to the supercomputer facility to manage the immense volumes of data which are generated in this research.

Flight Systems

Flight systems research includes activities in severe storm hazards, icing research and the Controlled Impact Demonstration program. The severe storm hazards flight test programs are illustrated in Figure 28. The highly instrumented F-106 research aircraft has continued the characterization of direct lightning strikes by intentionally flying into convective weather. From this aircraft, first-of-a-kind data is being used by DOD, FAA, and industry as threat models for materials and avionics protection. The NASA B-57B, also shown in Figure 28, has been used as a part of an interagency effort to measure the characteristics of low altitude atmospheric disturbances which influence flying through turbulent weather. During FY 1984, an interagency-sponsored doppler radar characterization of wind shear was completed. The data were applied to NASA and industry research, development, and training simulators to improve the pilot's ability to cope with hazardous wind-shear and turbulence conditions. Flight research to characterize clear air turbulence was completed. The B-57B continued flight research in low

altitude turbulent conditions to collect data on turbulence in a representative crossection of atmospheric conditions for improving aircraft design and operational safety.

An Interagency (NASA, FAA, DOT, NSF, NOAA, OFCM) National Aircraft Icing plan was completed this past year. NASA research elements of this plan are illustrated in Figure 29. NASA conducts research in the areas of analysis and modeling, wind tunnel studies in our unique icing facilities, and flight testing to verify scale effects and special conditions. In the past year, modern icing instrumentation devices were successfully flown on a NASA Twin Otter research aircraft in a wide variety of icing conditions to establish the basis for national standards. NASA and the Army completed in-flight evaluations of an operational pneumatic deicing boot on the leading edge of a helicopter main rotor blade.

The NASA/FAA remotely piloted full-scale transport Controlled Impact Demonstration (CID) is illustrated in Figure 30. The purpose was to demonstrate and validate technology to improve transport aircraft passenger crash surviability. The aircraft is shown approaching at 146 knots in the top right, impact at the center with the post crash fire at lower left. This flight demonstration of antimisting kerosene fuel, the major FAA experiment, also included characterization of fuselage and seat response at and following impact. As shown in Figure 31, full scale instrumented fuselage sections were drop tested and results were compared with analytical models. Full scale complex fuselage/wing structural models were also developed for the CID aircraft (Boeing 720). High quality data were obtained during the CID impact test, and comparisons with models and analysis of test results are now underway. A time history of the accelerations measured during the impact is shown in the lower right of Figure 31. The results are being used by FAA in decisions for rule making and by NASA for validation of structural impact dynamic prediction models.

In FY 1986, the Aviation Safety program will continue fixed and rotary-wing aircraft icing research in compliance with the National Aircraft Icing Plan. A major element will be the NASA/Army flight testing of an advanced rotorcraft icing protection concept developed by NASA and tested in the NASA Icing Research Tunnel. Flight research will continue the characterization of weather hazards associated with severe storms, including lightning, turbulence, winds, wind shear, and heavy rain. The resulting data will be used for development of advanced lightning protection concepts and practices, aerodynamic performance degradation determinations, aircrew training, and design of advanced remote detection devices for hazard avoidance and cockpit displays.

High-Performance Aircraft

High-performance Aircraft flight research programs are focused on providing the validated data base required for potential military and civil applications. Program objectives are accomplished by analysis, ground-based simulations, wind tunnel experimental research, and flight research. In many cases, joint funding and technical support is provided by other government agencies.

In the joint NASA/Air Force Advanced Fighter Technology Integration (AFTI) program, the AFTI/F-16 automated maneuvering attack system flight phase was initiated and will be completed in FY 1986. The AFTI/F-111 mission adaptive wing aircraft is in final preparation for a flight test program beginning in the fourth quarter of FY 1985 to evaluate the benefits of in-flight adjustment of wing camber. In the F-15 Highly Integrated Digital Electronic Control (HIDEC) program, flight research testing has begun to validate performance improvements by use of an adaptive engine control system.

In the NASA/DARPA X-29A Forward-Swept Wing (FSW) flight demonstration program, the aircraft, shown in Figure 32, has begun the baseline flight program. The X-29A, in addition to the forward-swept wing, incorporates an array of advanced technologies including a closely coupled canard, flight crucial digital controls, negative static stability, and three surface longitudinal control. All have been integrated to provide a technologically superior, agile and maneuverable aircraft. In FY 1986, the X-29A aircraft will complete its flight research program to fully evaluate the technologies designed into the aircraft.

The preliminary design of an oblique wing research aircraft, illustrated at the top of Figure 33, is being initiated. This joint program with the Navy will develop an experimental aircraft for an FY 1989 flight program that will extend oblique wing technology to transonic and supersonic speeds. The aerodynamic advantage of oblique wing concepts over conventional swept wing configurations is shown on the lower left. The loiter/dash superiority of the oblique wing over fleet operational aircraft is shown in the lower right. This program builds on a significant technology base which NASA initiated in 1945. As shown in Figure 34, additional wind tunnel investigations were accomplished in the 1970-72 time period, and later carried to flight with Remotely Piloted Research Vehicle tests in 1976 and manned low-speed flight tests in 1981-82. The existing NASA F-8 Digital Fly-By-Wire Research Aircraft will be modified, as shown in Figure 35, as the research testbed for the flight program.

To enhance the U.S. capability to predict and exploit the high angle-of-attack flight regime, an F-18 test aircraft

has been acquired and is being modified for a FY 1986 flight research program. This will be closely integrated with analytical, wind tunnel, and ground simulation activities. In the powered-lift area, a YAV-8B Harrier is being modified for initiation of an FY 1985 flight program for simulator and low-speed aerodynamic performance validation. Additional aircraft modifications for advanced electronics, displays, and flight and engine control systems will be performed in FY 1986.

Rotorcraft Research and Technology

The joint DARPA/NASA RSRA/X-Wing program is continuing with modifications of the Rotor Systems Research Aircraft (RSRA) and fabrication of the X-Wing rotor system. An artist's concept of the final configuration is shown in Figure 36. Reliability and operational testing of the flight control system and other components is being conducted. The RSRA/X-Wing will continue modification and system tests in preparation for the flight test program starting in late FY 1986.

In addition, a significant portion of the Aeronautics R&T program supports the expanding rotorcraft segment of civil aviation and the increasing use of rotorcraft by the armed forces. Elements of NASA's rotorcraft technology program are implemented within the individual discipline areas previously discussed. The critical areas which focus the discipline research for rotorcraft are: (1) noise reduction, (2) vibration reduction, (3) integration of advanced technologies that facilitate vehicle and mission management under intense workload in adverse environments. I'd like to briefly review these rotorcraft focused research activities.

The key to reducing rotorcraft noise is an understanding of the unsteady aerodynamic environment of the rotor system. A wind tunnel experiment with a 1/6 scale UH-60 helicopter, was conducted using a laser velocimeter to map the rotor wake (Figure 37). In a follow-on test, blade surface pressure distributions, airloads, vibrations and acoustic data will be measured and the results compared with in-flight data and analytical predictions.

Reduction of rotorcraft vibrations requires an understanding of rotor dynamics and fuselage structure interaction. Composite materials are being evaluated to determine their fatigue life and vibration attenuation. A significant reduction in vibrations was achieved during flight tests on an OH-6A helicopter with higher harmonic control. This joint Army/NASA program uses an electronic, computer controlled, vibration suppression system that reduces vibrations at the rotor. NASA is continuing to explore the use of active control systems to reduce vibration and to improve performance and handling qualities.

The third focus of NASA's rotorcraft research is in the integration of several rapidly advancing technology areas such as integrated flight and propulsion control systems, guidance and navigation concepts, cockpit displays and simulation capabilities. The critical issue is the human interface with these complex systems and how to optimize it to accomplish demanding operational tasks such as single crew member nap-of-the-earth flight to remote sites in adverse weather conditions. Shown in the lower part of Figure 37, is the Army procured advanced cab and visual display system which will be used on the NASA Vertical Motion Simulator as a principal research tool to investigate these integrated and individual concepts.

Hypersonic Cruise Technology

NASA has historically maintained a level-of-effort program in the critical technology areas of propulsion, propulsion/airframe integration, and high temperature structural concepts for hypersonic applications. Concern about the nation's commitment in the area was manifested during last year's NASA authorization hearing in which this Committee requested NASA to prepare a high-speed aeronautics technology plan. NASA's report "A Focused Hypersonic Research Program" was submitted in December 1984. It should be recognized that this report is preliminary. The level of resources required and the specific directions that should be taken will be developed in planning the NASA aeronautics program for FY 1987.

As mentioned in the report, NASA's ongoing research activities are directed at critical technologies with the major emphasis in recent years concentrated in two areas (1) propulsion; specifically the dual mode SCRAMJET engine technology and (2) the technically complex propulsion/airframe integration technologies.

The dual mode SCRAMJET propulsion system module is illustrated in Figure 38. The technology base for this concept has been developed on research scale models to the point that a large system module can be built and tested. During FY 1986, final design will be completed and fabrication initiated on such a module. This module will be tested in the Langley 8-foot High Temperature Tunnel in 1988. It is important to recognize that this engine concept, which is unique to NASA, has demonstrated a number of important firsts including, stable transition from subsonic to supersonic combustion using two different fuels and with a positive thrust/drag ratio in the supersonic combustion mode.

The Propulsion/Airframe integration area is technically complex because of the altitude and speed regimes that must be addressed. Self-acceleration of the aircraft to hypersonic cruise speed requires dual engine or hybrid

engine concepts. High altitude operation requires an inlet with a large capture area which increases the drag penalty. One dual engine concept studied has been the over/under engine installation illustrated on the top right of Figure 38. In this concept a turbojet is used for take-off and acceleration to supersonic speed where a ramjet begins operating. As the performance of the turbojet decreases with higher flight speeds the ramjet performance improves. An efficent variable geometry inlet must be developed that is also capable of partitioning the incoming air between the two engines at all flight conditions. The inlet must operate over the 0-5.0 Mach number speed range and from sea level to the 150,000 ft. cruise altitude. Analysis and design of a wind tunnel model of this type of inlet has been underway for two years. Recently, advanced computational techniques for supersonic flow in internal ducts have been developed and are being applied to the design of this inlet. As shown in Figure 38, the analysis can predict the flow Mach number and secondary velocities at any point in the supersonic portion of this rectangular inlet. As a result of this analysis the internal contours of the inlet model have been redesigned. Construction of the model should begin during 1986 and testing is planned for the 10x10 Supersonic Wind Tunnel at NASA Lewis in late 1987.

Planning for the Future

In striving to maintain an aggressive and forward looking program of aeronautical research and technology, NASA annually conducts comprehensive strategic and long range planning activities that form the basis for establishing priorities in the budget process. We receive inputs from all sectors of the aeronautics community through an extensive and diverse range of formal and informal advisory groups. Some of the key sources of this external advice are shown on figure 39. The Aeronautics Advisory Committee is comprised of industry, university, and government technical experts in each of the important aeronautical discipline and vehicle class areas. They have been a rich and valuable source over the years of recommendations on future requirements and technical opportunities as well as on the content, direction and pace of specific research activities. This mechanism has helped to ensure that our programs are responsive to national needs and focused in the highest leverage areas. Even though NASA and DoD aeronautical R&T programs are well coordinated at the working level, the Aeronautics and Astronautics Coordinating Board provides a senior level NASA/DoD forum for communicating technical requirements and exchanging information on current and future program directions. Many of the joint and cooperative programs with the DoD that I have described in our FY 1986 Budget are a result of discussions and agreements reached in this forum.

The Aeronautics and Space Engineering Board (ASEB), established to focus the talents and energies of the engineering community on significant aerospace policies and programs, also conducts independent periodic reviews of the NASA aeronautics program. In addition, the Congressional Advisory Committee on Aeronautics has brought together a highly respected group of industry and university experts to provide the Congress with an independent analysis of the NASA Aeronautics program. They have completed their initial review and we are looking forward to their constructive recommendations.

As many of you know, the Office of Science and Technology Policy (OSTP) has established a senior level Aeronautical Policy Review Committee to review the implementation of the Administration's Aeronautical Policy announced in November 1982. This OSTP committee, in a November 1983 report to the President's Science Advisor, made several recommendations regarding the content and future direction of the NASA aeronautics program. Among the key recommendations expressed by the committee were the need for a bolder, more aggressive vision for aeronautics, additional focus in high-payoff technology areas, and the reinstitution of an active flight research and experimental aircraft program. These positions have been strongly supported by the Congress and NASA advisory committees.

The recommendation that NASA develop a more visionary plan for aeronautics was quite far-reaching, and a significant effort in 1984 was directed at developing these visions for the year 2000 in conjunction with DOD, industry and the university community. The forum to obtain inputs was provided by the National Research Council's Aeronautics and Space Engineering Board (ASEB) which, at NASA's request, conducted a workshop to project what the state of aeronautical knowledge and technology could be if the necessary resources were made available. As a follow-on activity, an ASEB Vehicle Applications Panel was asked to consider the integrated effects of the discipline technology advances predicted by the workshop and the advanced vehicle concepts that might evolve from them. The results of these activities confirmed and extended many earlier assessments. Significant evolutionary and revolutionary advances are definitely possible which could technologically obsolete virtually all civil and military aircraft that are operational today. Also, the range of exciting, high-payoff opportunities will far exceed the resources available for investment. The skillful integration of the projected technology advances will make possible U.S. aircraft of higher speeds, altitudes, maneuverability, and efficiency coupled with lower drag, lower observability, lighter weight, longer range, more flexible landing and takeoff capabilities, and lower manufacturing and maintenance costs.

To achieve these projected advances in a world of real and growing fiscal constraints requires a perceptive and realistic strategy for the future. NASA will continue to direct the R&T base and institutional capabilities toward the key, high-leverage discipline technologies applicable to the safety and efficiency of all aeronautical vehicles. Critical, pervasive technologies such as computational methods (for prediction of fluid flows, structural mechanics and control dynamics), advanced materials and interdisciplinary design and analysis methods for highly integrated and interactive controls will be emphasized. Essential technologies for revolutionary advances in efficiency and productivity for a new generation of military and civil subsonic transports and rotorcraft will be readied including efforts to maximize the relevance and applicability of these technology advances to general aviation and commuter aircraft.

Coupled with these research thrusts will be longer term efforts in the higher speed flight regimes to establish technology readiness for efficient, long-distance supersonic cruise and to explore technology options for significant improvements in fighter aircraft capabilities and for realization of practical hypersonic/-transatmospheric flight. These areas will receive increasing emphasis as the subsonic technologies are completed and transferred to industry. However, the pace of technology advancements in these areas will be constrained by the resources available.

The summary I have presented today contains the highlights of our proposed FY 1986 aeronautics program. Today the convergence of technology opportunities in aeronautics is as great or greater than at any other time in our lifetime. The realization of these advancements will require dedicated effort and increased achievement. NASA is committed to playing a central role in the technology development required for superior U.S. civil and military aircraft in recognition that key elements of our national and economic security are linked to preeminence in aeronautics. This FY 1986 budget request builds positively on the momentum that has been generated with your support in the past. With your continued support, I am confident that we can move effectively towards realizing many of these exciting capabilities.

Thank you Mr. Chairman.

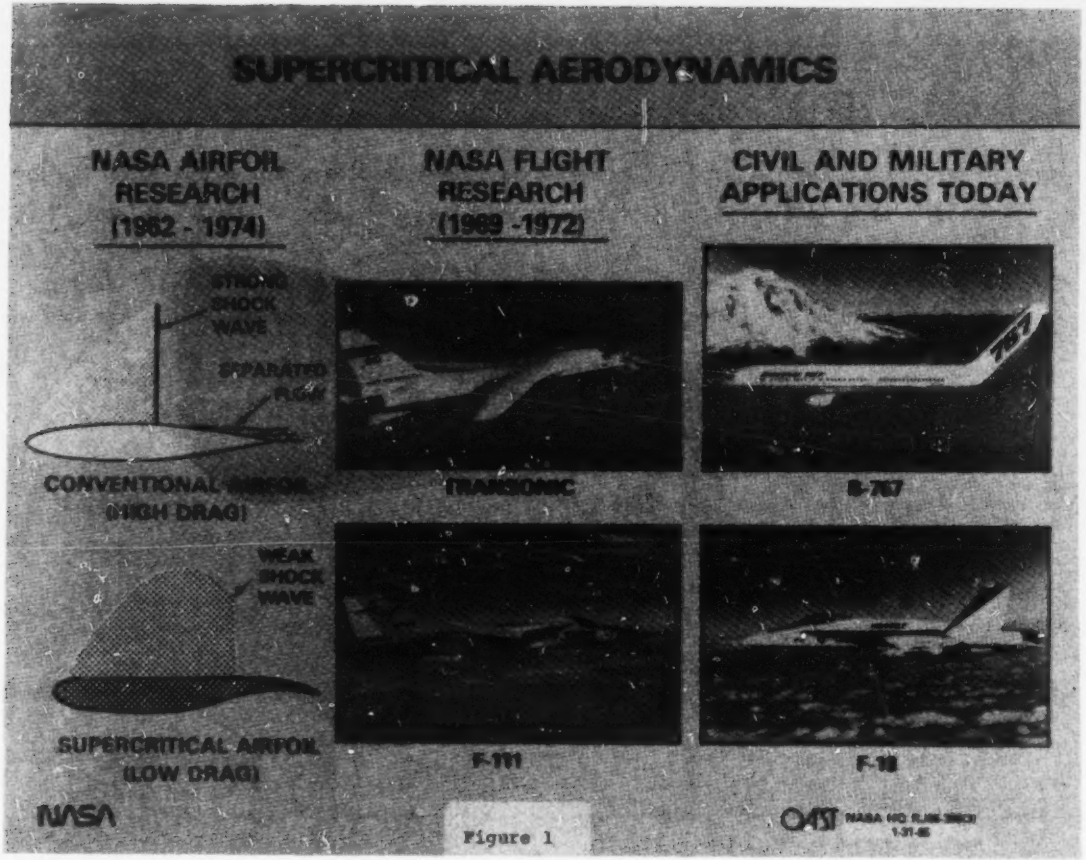

SUPERCRITICAL AERODYNAMICS
NASA AIRFOIL RESEARCH (1962 - 1974)
NASA FLIGHT RESEARCH (1969 -1972)
CIVIL AND MILITARY APPLICATIONS TODAY
STRONG SHOCK WAVE
SEPARATED FLOW
CONVENTIONAL AIRFOIL (HIGH DRAG)
TRANSONIC
B-767
WEAK SHOCK WAVE
SUPERCRITICAL AIRFOIL (LOW DRAG)
F-111
F-16
NASA
OAST

Figure 1

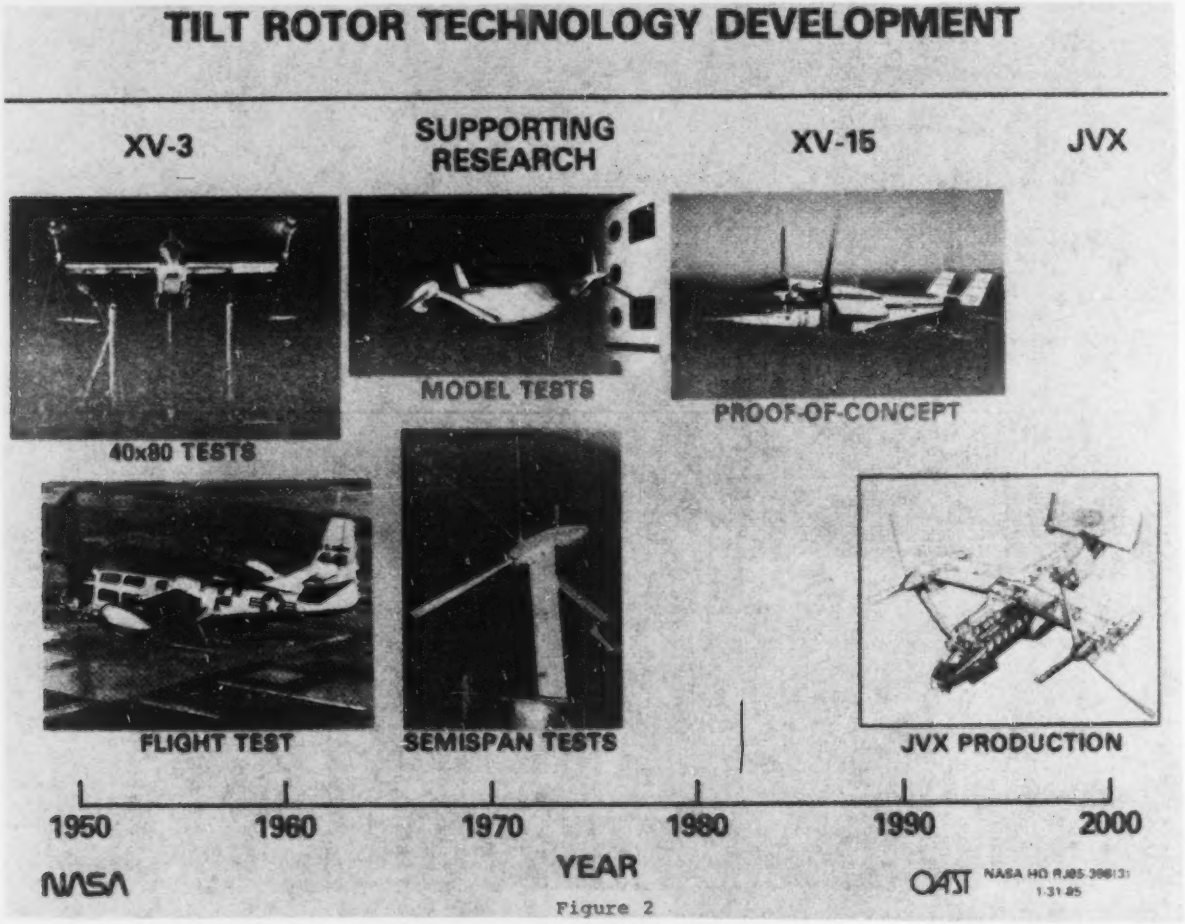
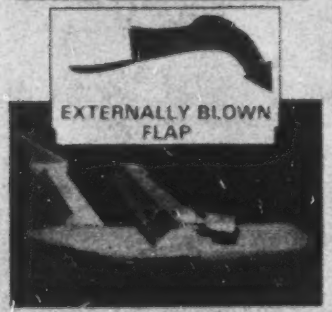

TILT ROTOR TECHNOLOGY DEVELOPMENT
XV-3
SUPPORTING RESEARCH
XV-15
JVX
40x80 TESTS
MODEL TESTS
PROOF-OF-CONCEPT
FLIGHT TEST
SEMISPAN TESTS
JVX PRODUCTION
1950
1960
1970
1980
1990
2000
YEAR
NASA
OAST
NASA HQ RJ85-39813
1-31-85

Figure 2

PROPULSIVE LIFT TECHNOLOGY

NASA WIND TUNNEL RESEARCH (1958-1982)	NASA/AIR FORCE FLIGHT TESTING (1976-1985)	APPLICATION (1987 I.O.C.)



QSRA

BOEING YC-14

McDONNELL DOUGLAS YC-15

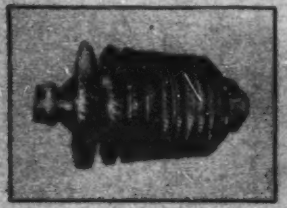
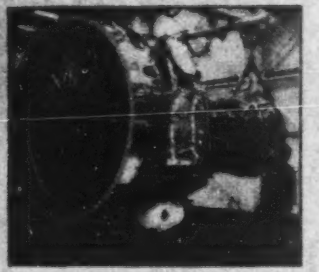
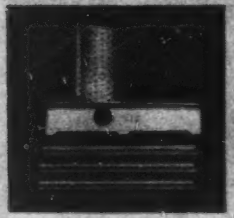
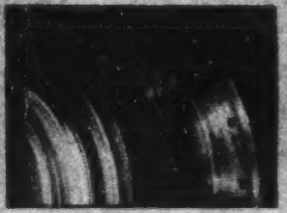
AIR FORCE C-17

NASA

OAST

Figure 3

ENERGY EFFICIENT PROPULSION TECHNOLOGY

NASA RESEARCH (1960-1980)	NASA EEE PROGRAM (1979-1983)	NASA EEE PROGRAM (1982-1983)	APPLICATION
TRANSONIC COMPRESSOR AIRFOILS	 HIGH PRESSURE RATIO COMPRESSORS	CORE EVALUATION	 PWA-2037 AND GE CF6-80C
 FILM COOLING	 HIGH TEMPERATURE TURBINES	SYSTEMS EVALUATION	

NASA

OAST NASA HQ RPIS 38(3) 1 30 85

Figure 4

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

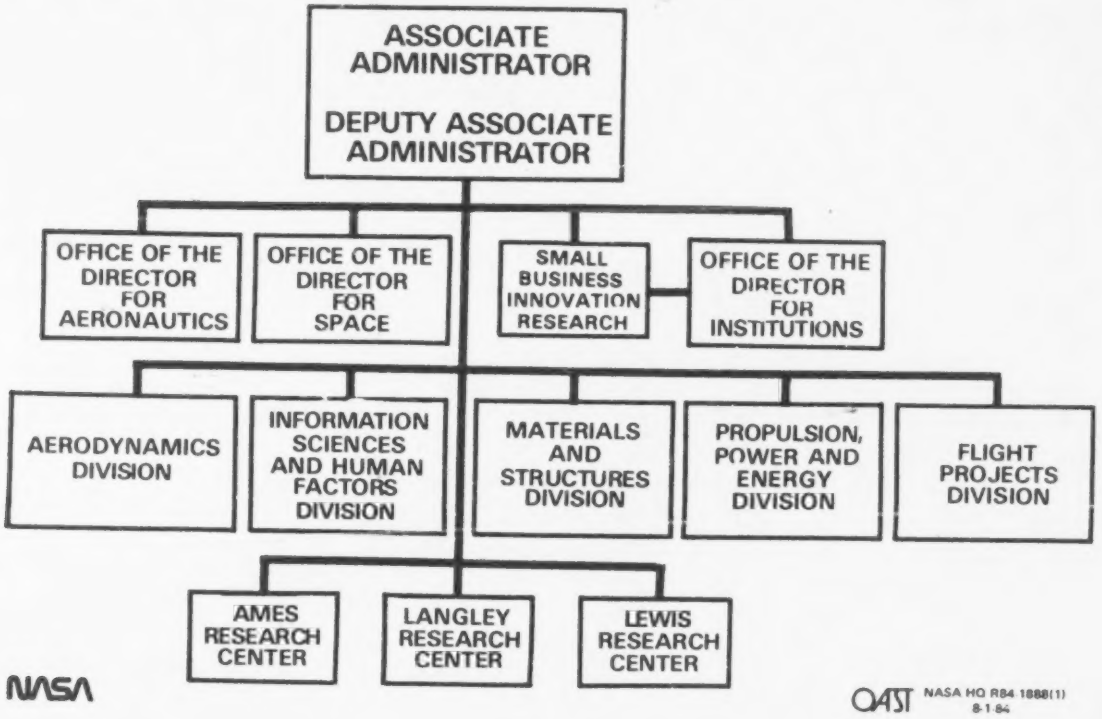


Figure 5

AERONAUTICS RESEARCH AND TECHNOLOGY

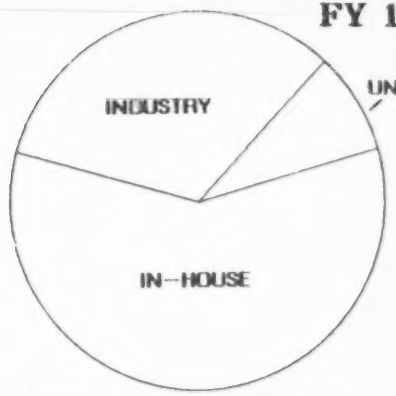
R&D BUDGET

	$, MILLIONS			
		FY 1985		FY 1986
	FY 1984	BUDGET ESTIMATE	CURRENT ESTIMATE	BUDGET ESTIMATE
RESEARCH & TECHNOLOGY BASE	228.5	233.3	223.3	239.3
SYSTEMS TECHNOLOGY PROGRAMS	86.8	109.1	119.1	114.7
TOTAL	315.3	342.4	342.4	354.0

Figure 6

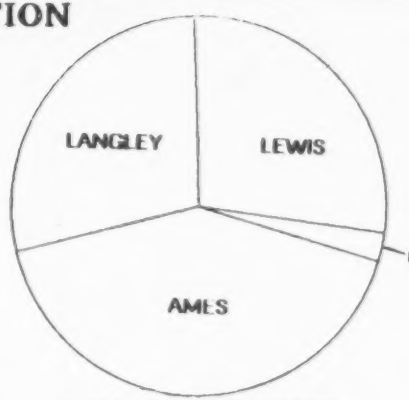
AERONAUTICS RESOURCES

FY 1986 DISTRIBUTION

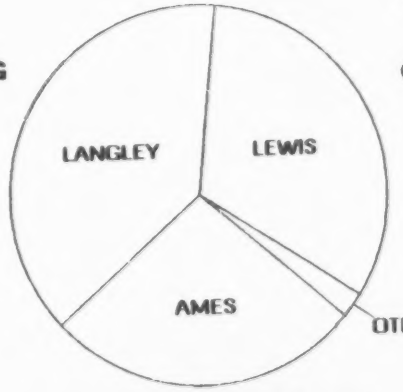


PERFORMER FUNDING

R&D FUNDS	$354M
MANPOWER	3,561



CENTER FUNDING



CENTER MANPOWER

Figure 7

AERONAUTICS RESEARCH AND TECHNOLOGY

DISTRIBUTION BY TECHNICAL AREA

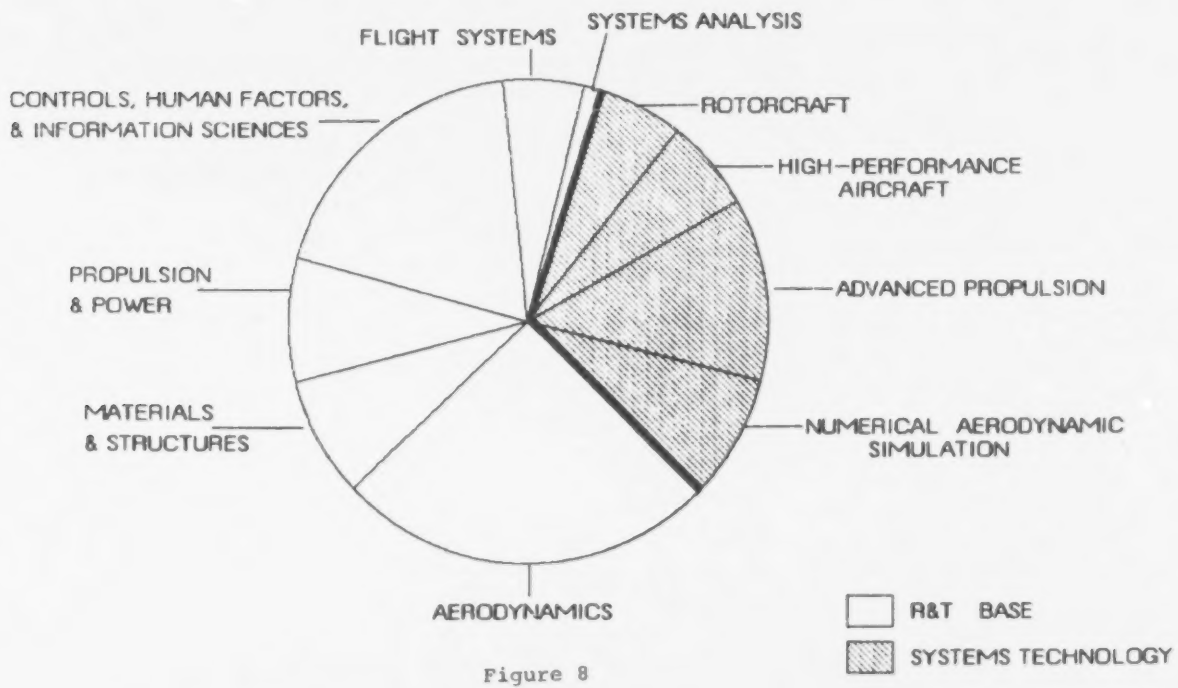


Figure 8

AERONAUTICS RESEARCH AND TECHNOLOGY

APPLICATIONS SUMMARY BY VEHICLE CLASS

(DOLLARS IN MILLIONS)

	GENERAL AVIATION	TRANSPORT	HIGH PERFORMANCE	ROTORCRAFT	GENERIC	FY 1986 BUDGET TOTAL DIRECT
DIRECT						
R&T BASE	8.9	28.0	66.3	31.5	104.6	239.3
SYSTEMS TECH. PROGRAMS	2.2	42.0	21.8	20.5	28.2	114.7
TOTAL	11.1	70.0	88.1	52.0	132.8	354.0
INDIRECT						
R&T BASE	51.4	102.8	78.9	52.8	–	–
SYSTEMS TECH. PROGRAMS	21.0	29.2	22.0	22.0	–	–
TOTAL	72.4	132.0	100.9	74.8	–	–

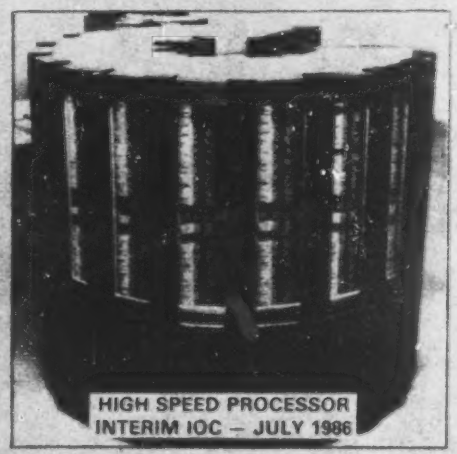
Figure 9

MAJOR NEW AERONAUTICS FACILITIES
NATIONAL TRANSONIC FACILITY
40 X 80 X 120 FOOT
WIND TUNNEL
NUMERICAL AERODYNAMIC SIMULATION
• NATIONAL FACILITIES
• MAJOR RESEARCH
CAPABILITIES
NASA
OAST

Figure 10

NUMERICAL AERODYNAMIC SIMULATION (NAS)

NATIONAL COMPUTATIONAL CAPABILITY



- NETWORK TESTBED DEVELOPMENT
- INTEGRATION AND SYSTEM SOFTWARE CONTRACTS AWARDED

CONTINUING DEVELOPMENT

- LONG HAUL COMMUNICATIONS SYSTEM
- HIGH SPEED PROCESSOR-2
- NAS FACILITY CONSTRUCTION

NASA

Figure 11

OAST

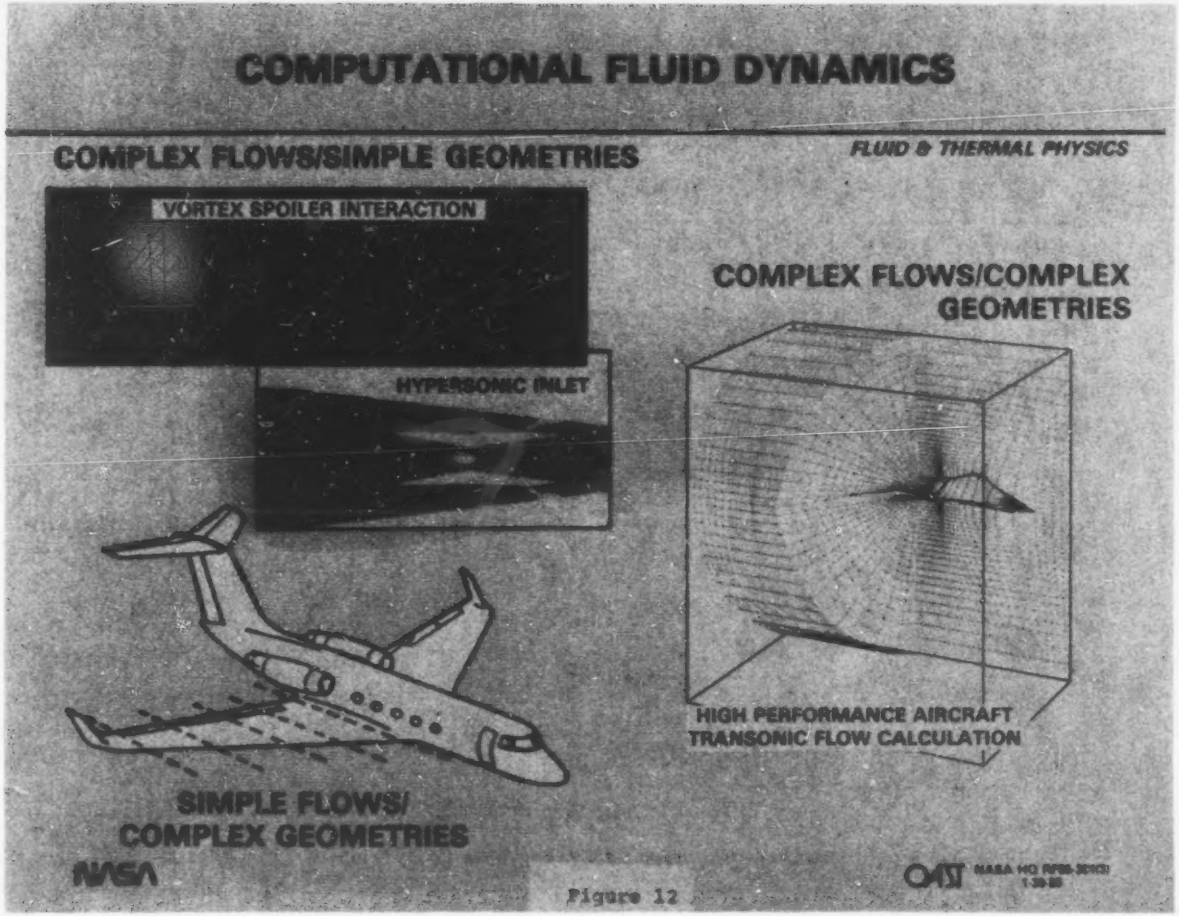

COMPUTATIONAL FLUID DYNAMICS
COMPLEX FLOWS/SIMPLE GEOMETRIES
FLUID & THERMAL PHYSICS
VORTEX SPOILER INTERACTION
HYPERSONIC INLET
SIMPLE FLOWS/
COMPLEX GEOMETRIES
COMPLEX FLOWS/COMPLEX
GEOMETRIES
HIGH PERFORMANCE AIRCRAFT
TRANSONIC FLOW CALCULATION
NASA

Figure 12

46-385 O—85—3

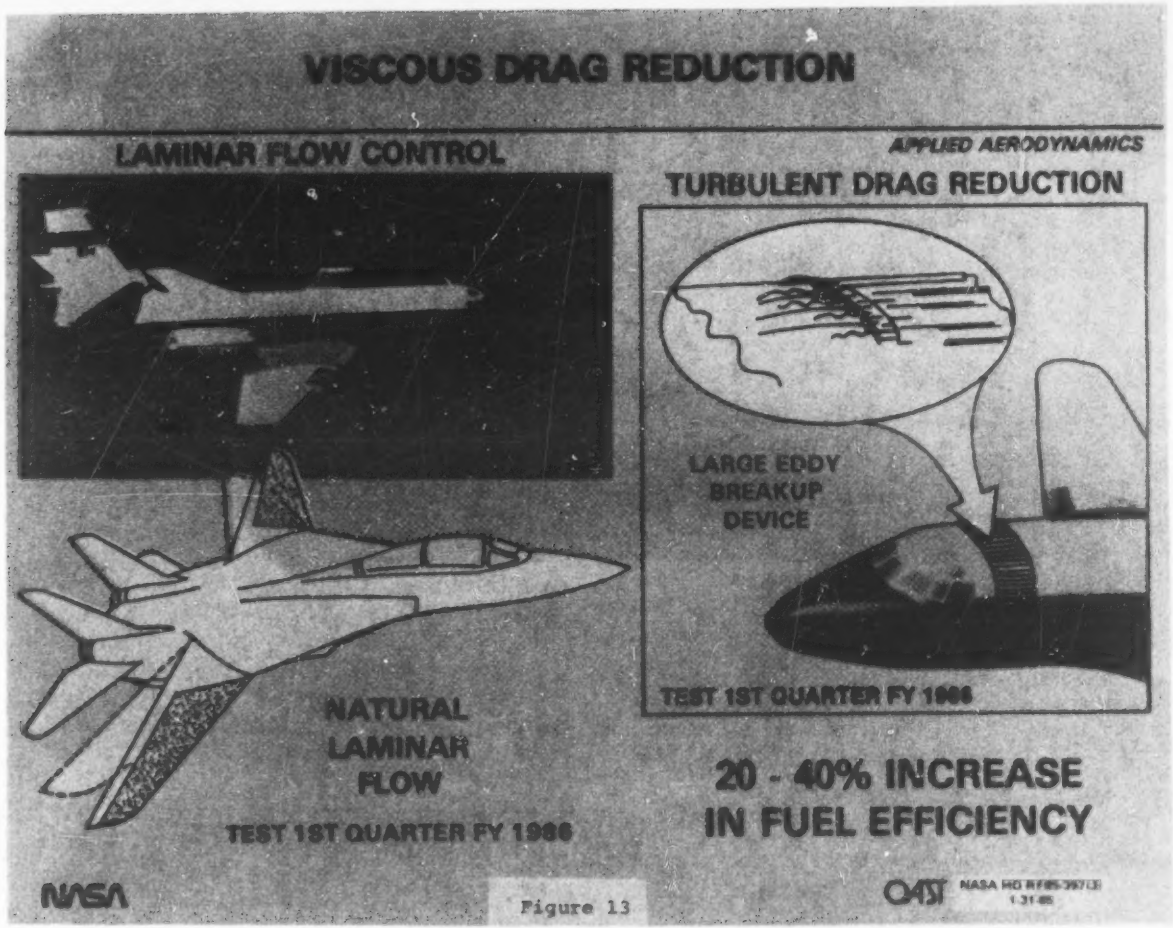
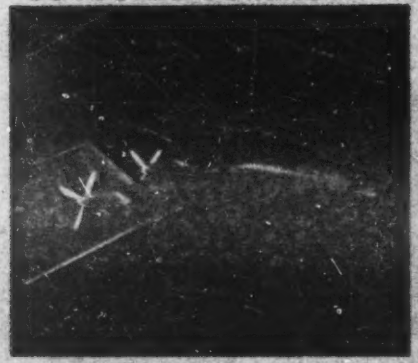


Figure 13

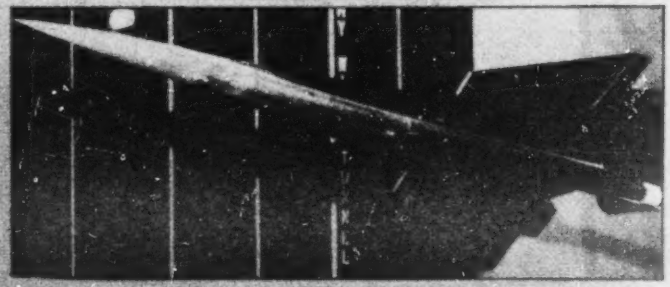
ADVANCED CONFIGURATION AERODYNAMICS

APPLIED AERODYNAMICS

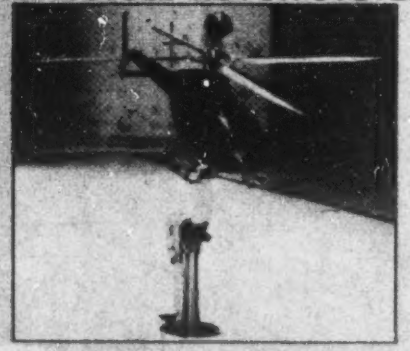
SUBSONIC COMMUTER

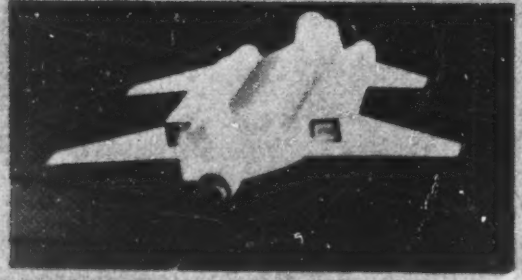


HYPERSONIC CRUISE



ADVANCED ROTOR SYSTEM





NASA SUPERSONIC STOVL

Figure 14

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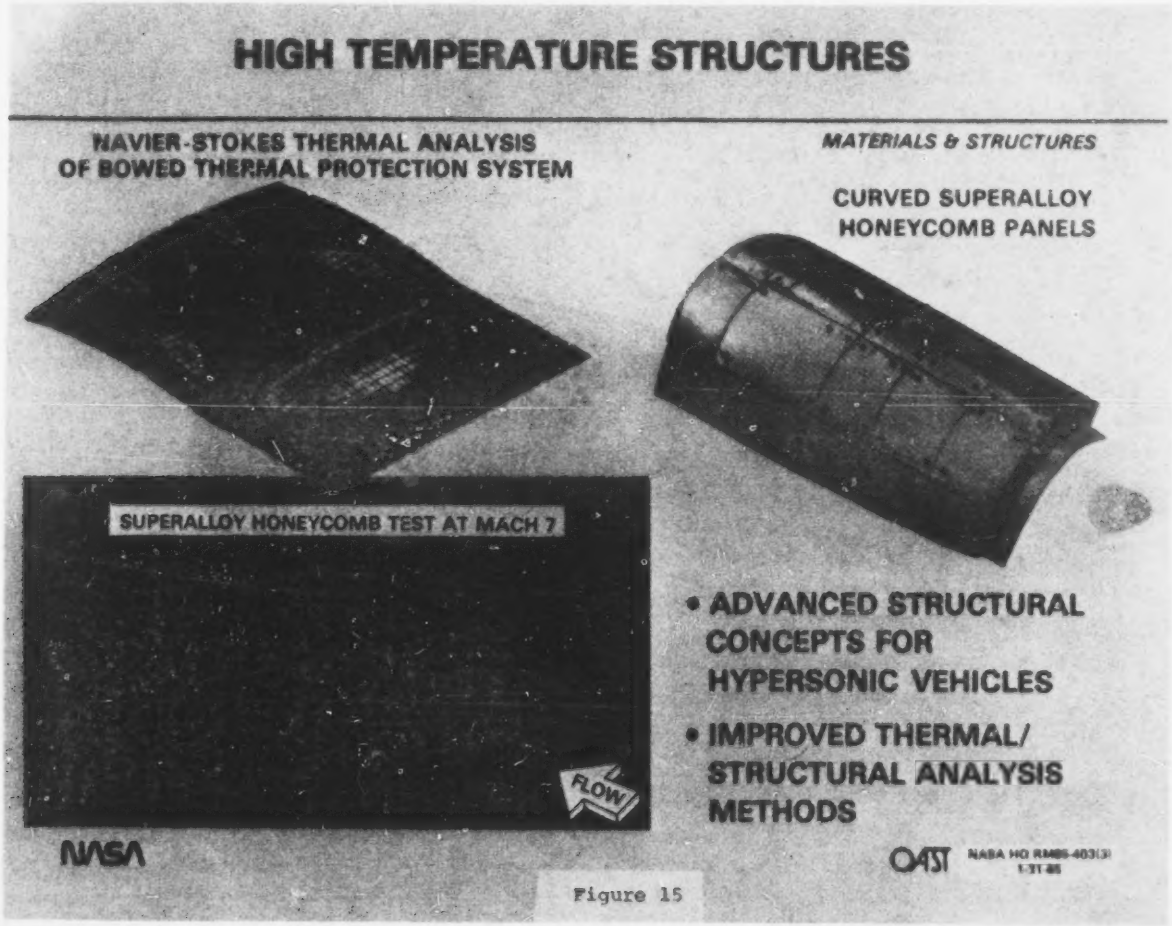

HIGH TEMPERATURE STRUCTURES
NAVIER-STOKES THERMAL ANALYSIS OF BOWED THERMAL PROTECTION SYSTEM
SUPERALLOY HONEYCOMB TEST AT MACH 7
FLOW
NASA
MATERIALS & STRUCTURES
CURVED SUPERALLOY HONEYCOMB PANELS
• ADVANCED STRUCTURAL CONCEPTS FOR HYPERSONIC VEHICLES
• IMPROVED THERMAL/ STRUCTURAL ANALYSIS METHODS
OAST

Figure 15

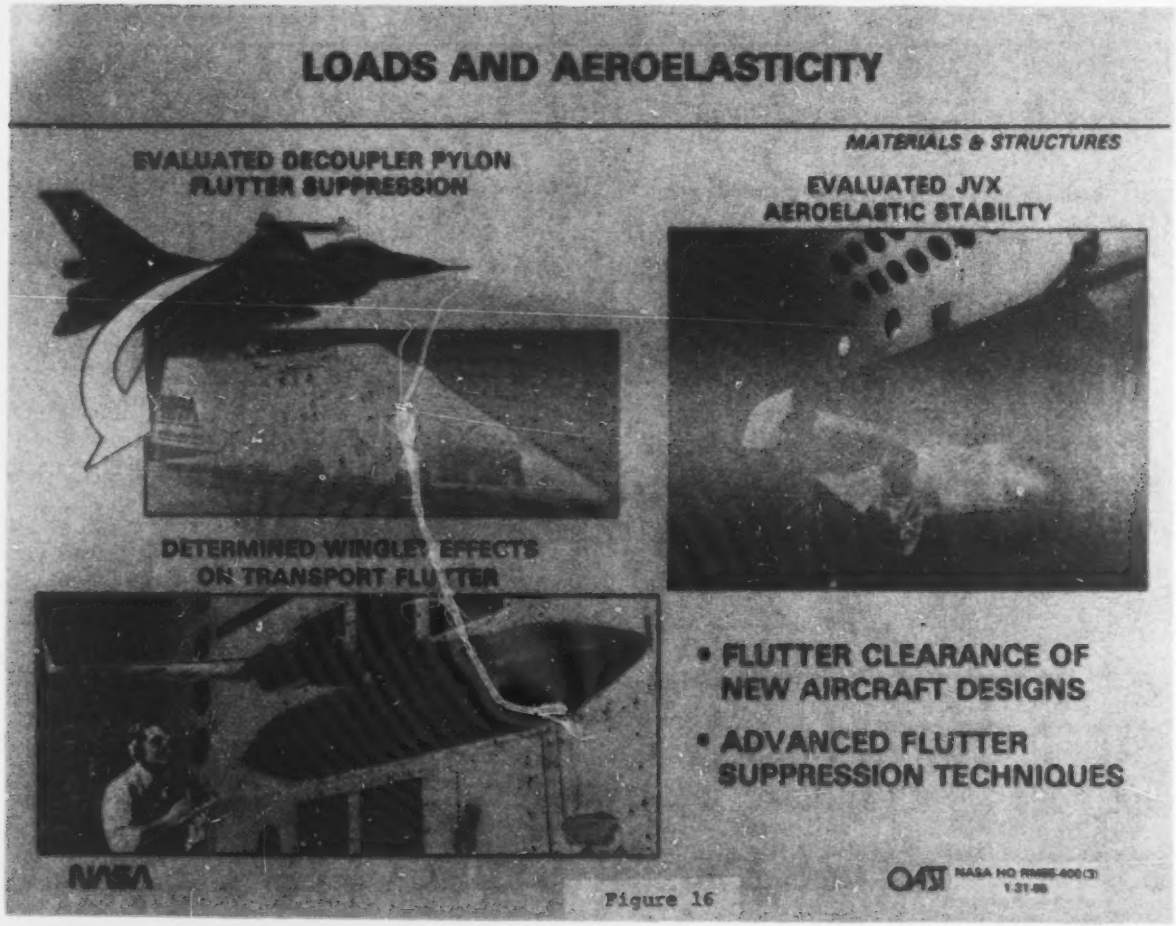

LOADS AND AEROELASTICITY
MATERIALS & STRUCTURES
EVALUATED DECOUPLER PYLON FLUTTER SUPPRESSION
EVALUATED JVX AEROELASTIC STABILITY
DETERMINED WINGLET EFFECTS ON TRANSPORT FLUTTER
• FLUTTER CLEARANCE OF NEW AIRCRAFT DESIGNS
• ADVANCED FLUTTER SUPPRESSION TECHNIQUES
NASA
OAST

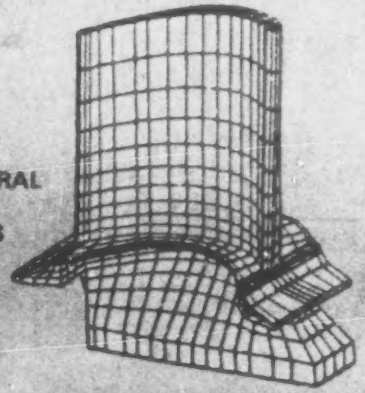
Figure 16

HOT SECTION TECHNOLOGY (HOST)

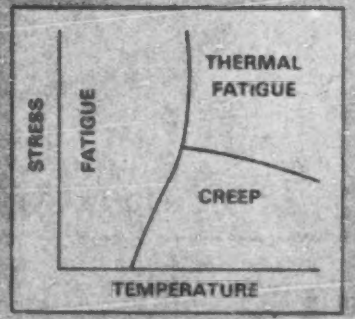
EVALUATED GAS PROBE FOR MEASURING COMBUSTOR FLAME FLUCTUATIONS

HIGH PERFORMANCE AIRCRAFT

DEVELOPED 3-D THERMAL-STRUCTURAL CODES FOR TURBINE BLADES



IDENTIFIED TURBINE BLADE FAILURE MODES



- IMPROVE DURABILITY OF TURBINES
- ADVANCE ANALYTICAL AND LIFE PREDICTION SYSTEMS

NASA

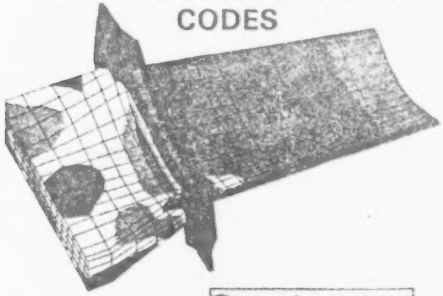
OAST

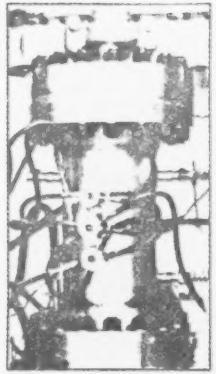
Figure 17

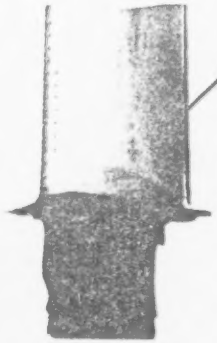
CERAMICS

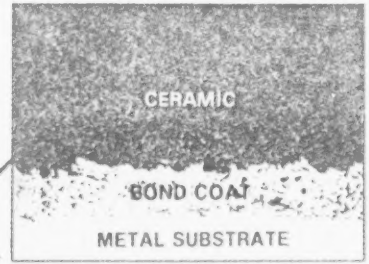
MATERIALS & STRUCTURES

DEVELOPED ADVANCED 3D STRUCTURAL ANALYSIS CODES









DEVELOPED PROTECTIVE COATINGS THAT MEET THERMAL/OXIDATION REQUIREMENTS

APPLIED SINTERING PROCESS TO IMPROVE SILICON CARBIDE STRENGTH

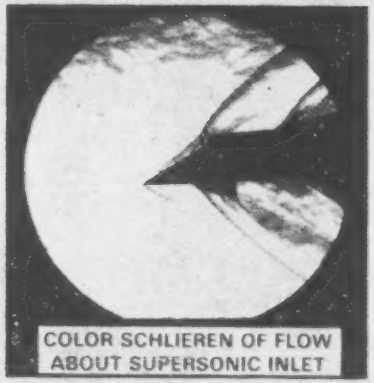
NASA

Figure 18

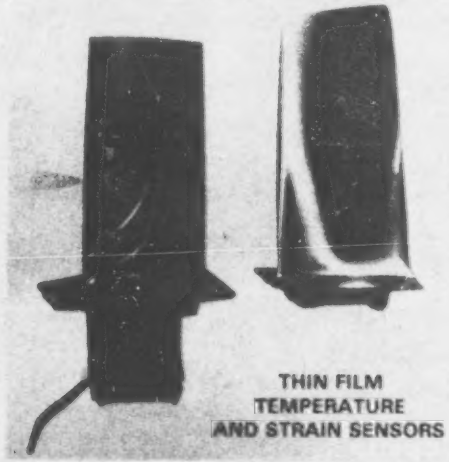
OAST NASA HQ BM85 3893 1 30 85

PROPULSION INSTRUMENTATION

NON-INTRUSIVE



MINIMALLY-INTRUSIVE



ENABLING TECHNOLOGY FOR PROPULSION RESEARCH

NASA

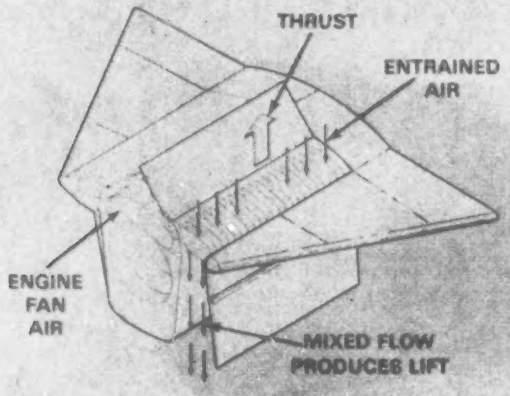
Figure 19

OAST

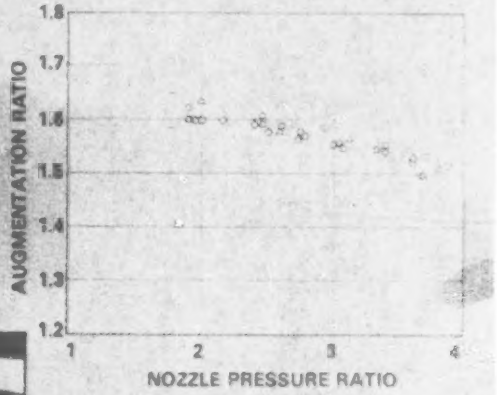
STOVL PROPULSION INTEGRATION

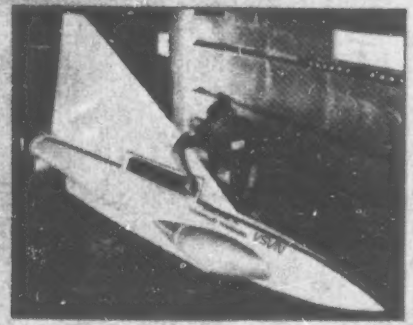
PROPULSION & POWER

EJECTOR CONCEPT



EXPERIMENTAL EJECTOR LIFT AUGMENTATION





SEMI-SPAN E-7 AIRCRAFT MODEL

NASA

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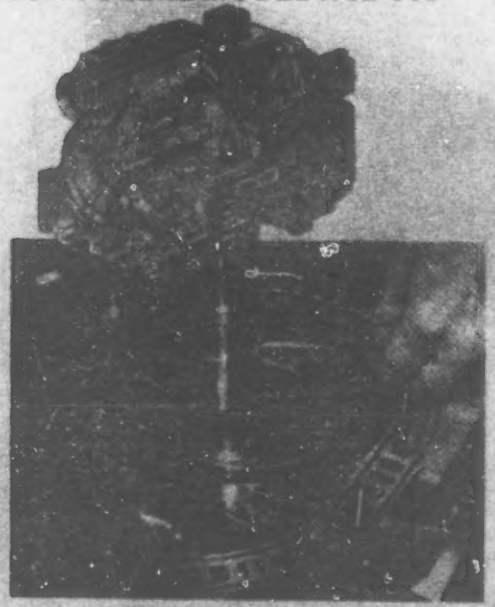
Figure 20

INTERMITTENT COMBUSTION ENGINE TECHNOLOGY

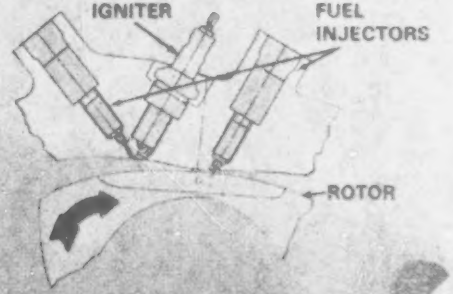
PROPULSION & POWER

ROTARY COMBUSTION ENGINE
JOHN DEERE MODEL RC2-350

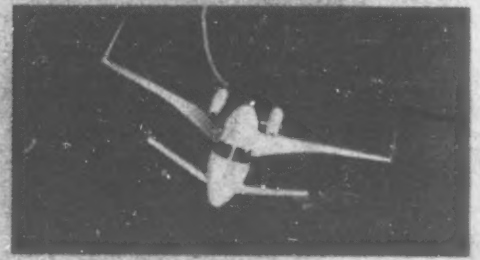


SINGLE ROTOR TEST RIG

STRATIFIED CHARGE CONFIGURATION



ROTARY ENGINE APPLICATION



NASA

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NASA HQ RP85 3(6/3)
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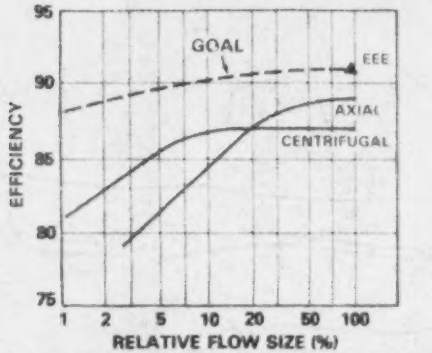
Figure 21

SMALL ENGINE TECHNOLOGY

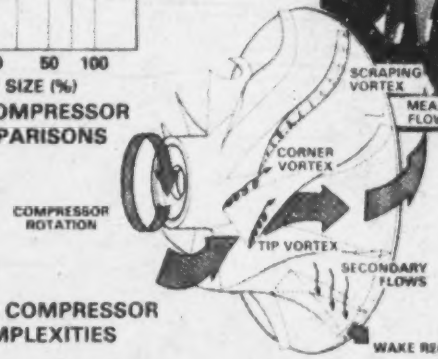
PROPULSION & POWER

EXPERIMENTAL AND ANALYTICAL MODELING



AXIAL/CENTRIFUGAL COMPRESSOR
PERFORMANCE COMPARISONS

LARGE, LOW SPEED
RESEARCH COMPRESSOR



CENTRIFUGAL COMPRESSOR
FLOW COMPLEXITIES

NASA

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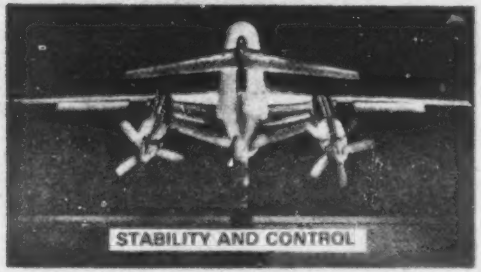
Figure 22

ADVANCED TURBOPROP PROGRAM

ADVANCED PROPULSION

SUPPORTING R&T



LARGE-SCALE VERIFICATION

LARGE-SCALE GEARBOX TECHNOLOGY

SINGLE ROTATION FLIGHT TEST

NASA

OAST NASA HQ RP85-37231 1-30-85

Figure 23

ATP PROGRAM PLAN

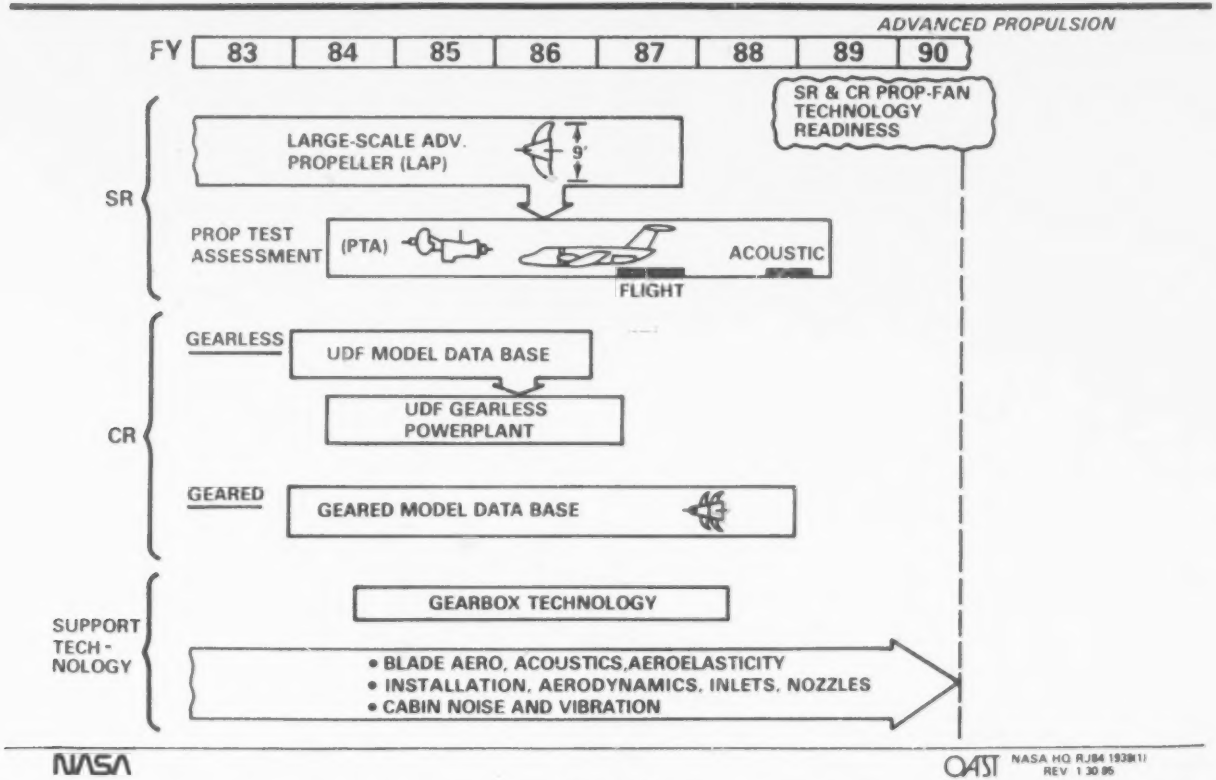


Figure 24

ADVANCED TRANSPORT OPERATING SYSTEMS

CONTROLS & GUIDANCE

FLIGHT PATH OPTIMIZATION AND 4D GUIDANCE WITH FUTURE NATIONAL AIRSPACE SYSTEM

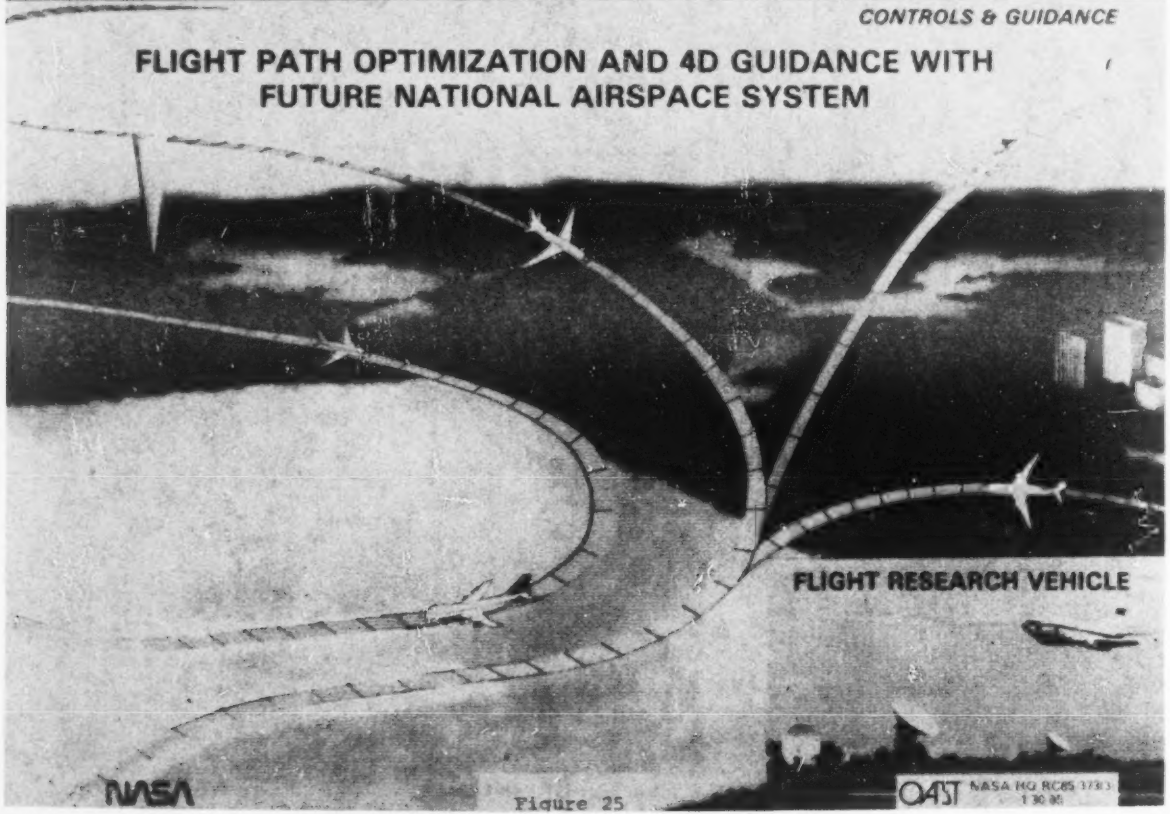
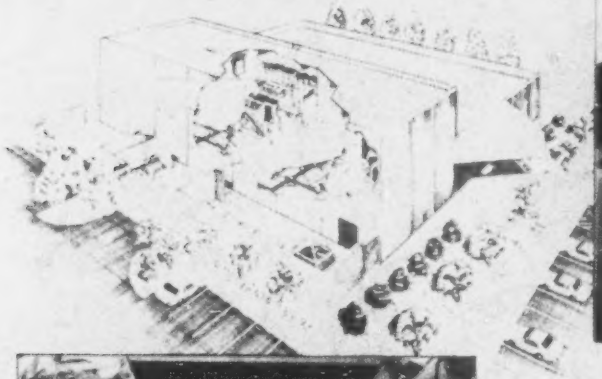


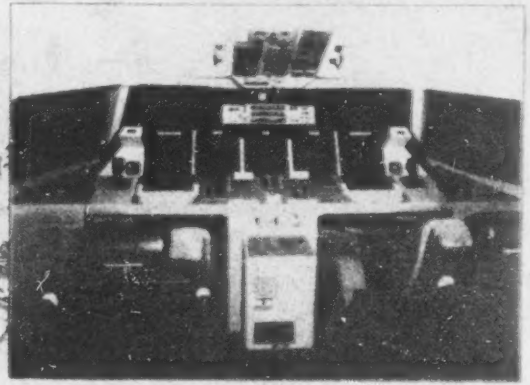
Figure 25

AIRCREW/AUTOMATION INTERFACE

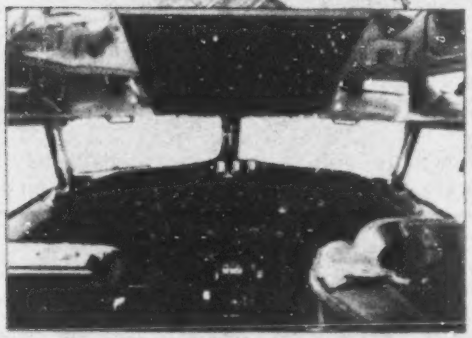
HUMAN FACTORS

MAN VEHICLE SYSTEM RESEARCH FACILITY





ADVANCED COCKPIT SIMULATOR



727 COCKPIT SIMULATOR

- SUPERVISORY CONTROL OF AUTOMATION
- CREW/COMPUTER INTERACTION
- HUMAN-MATCHED ELECTRONIC DISPLAYS
- COGNITIVE WORKLOAD MEASURES

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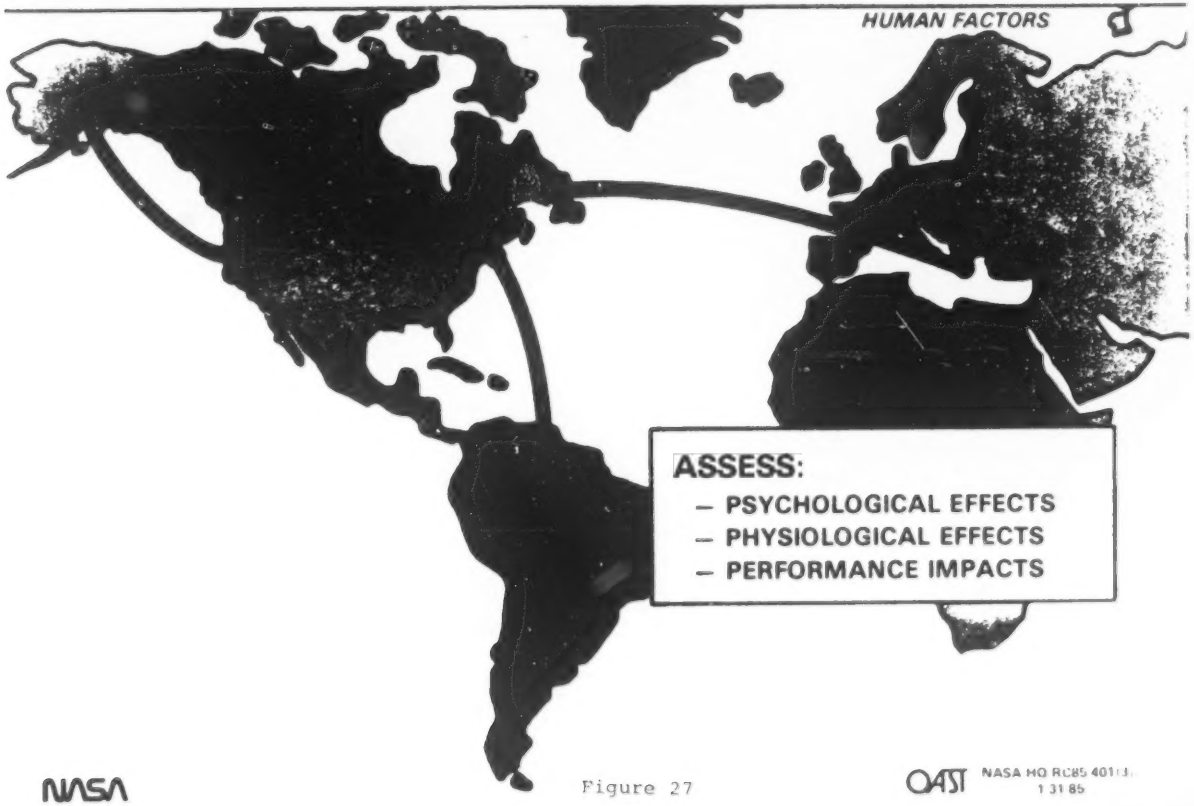
CIRCADIAN DESYNCHRONOSIS FIELD STUDY



NASA

Figure 27

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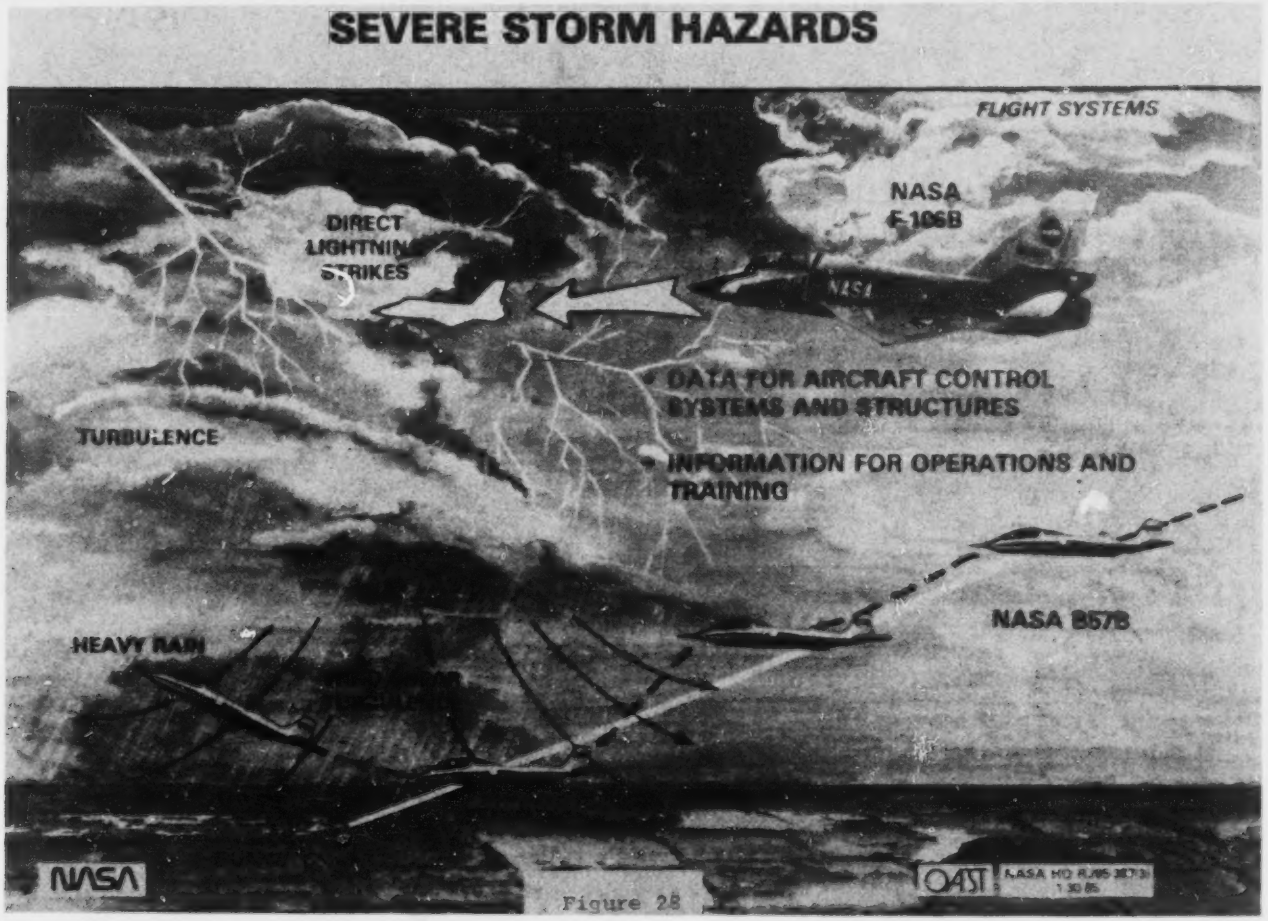

SEVERE STORM HAZARDS
FLIGHT SYSTEMS
NASA
F-106B
DIRECT
LIGHTNING
STRIKES
• DATA FOR AIRCRAFT CONTROL SYSTEMS AND STRUCTURES
TURBULENCE
• INFORMATION FOR OPERATIONS AND TRAINING
NASA B57B
HEAVY RAIN
NASA
OAST

Figure 28

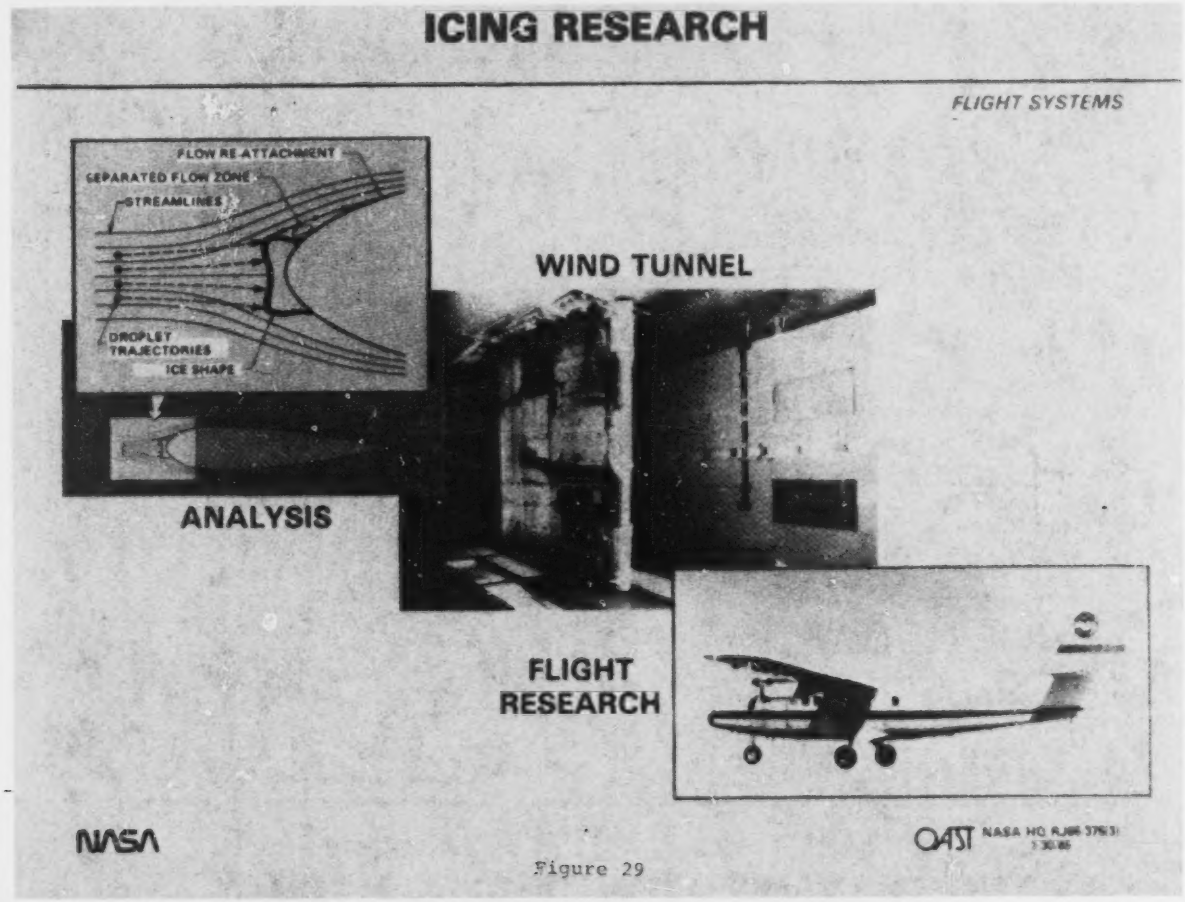
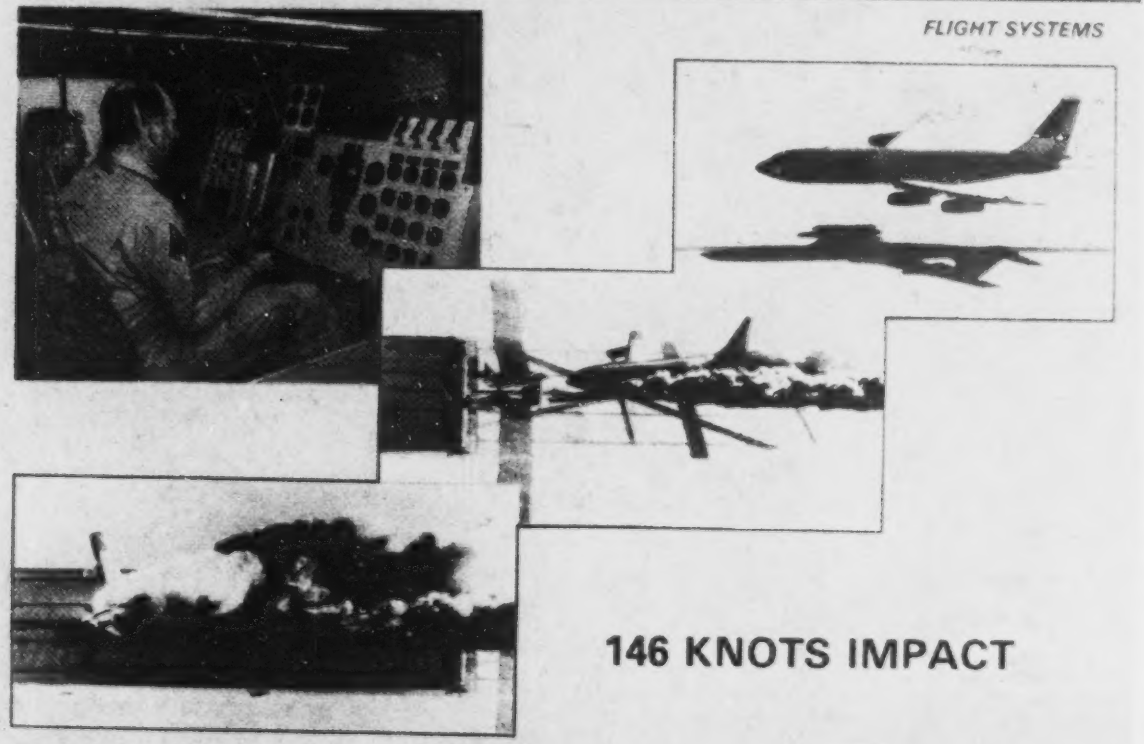

ICING RESEARCH
FLIGHT SYSTEMS
FLOW RE-ATTACHMENT
SEPARATED FLOW ZONE
STREAMLINES
DROPLET TRAJECTORIES
ICE SHAPE
WIND TUNNEL
ANALYSIS
FLIGHT RESEARCH
NASA
OAST

Figure 29

CONTROLLED IMPACT DEMONSTRATION (CID)



46-385 111

NASA

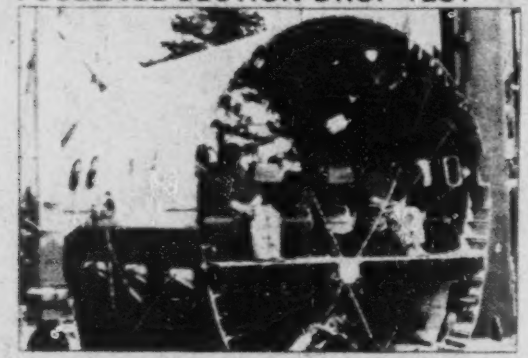
Figure 30

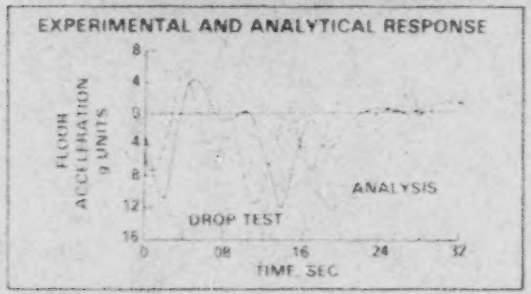
OAST

CID STRUCTURES RESEARCH

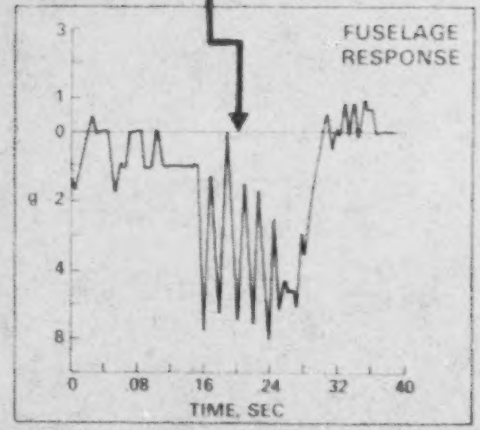
MATERIALS & STRUCTURES

FUSELAGE SECTION DROP TEST





FULL SCALE IMPACT TEST



NASA

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Figure 31

X-29A EXPERIMENTAL AIRCRAFT

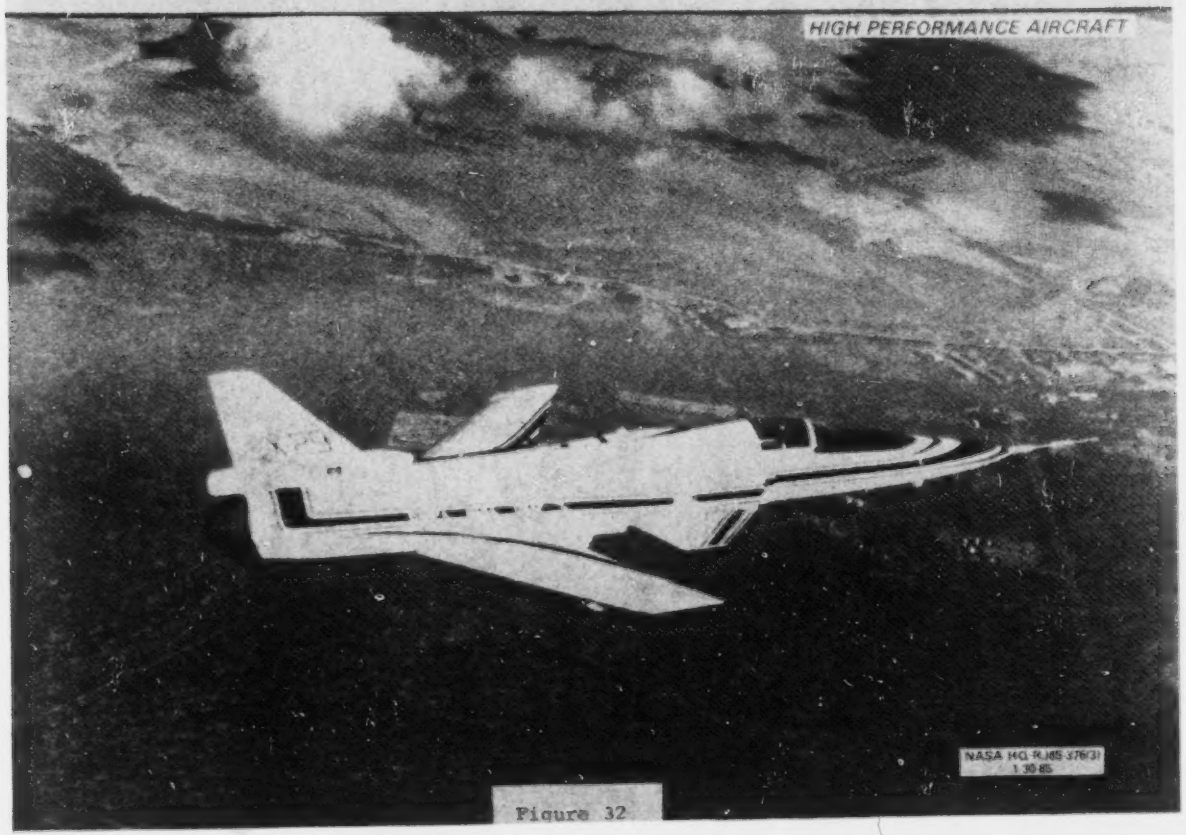
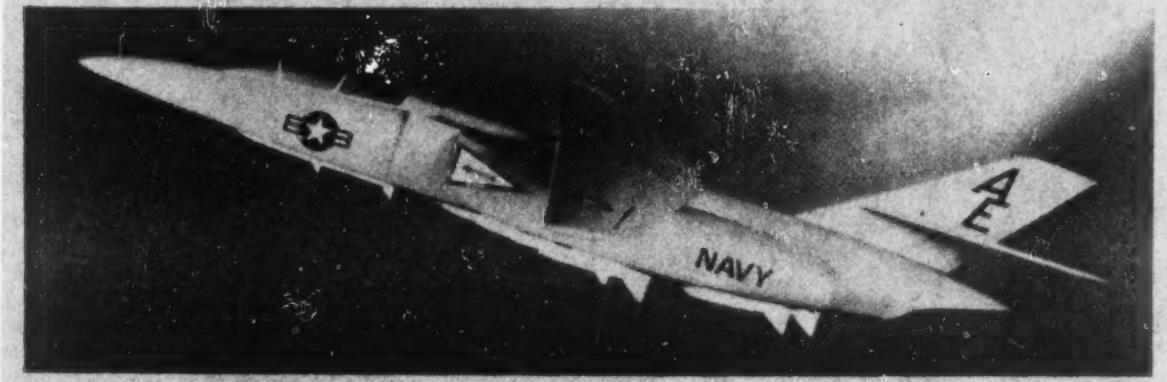


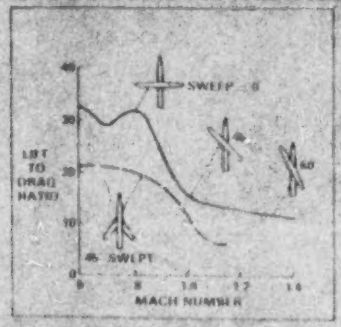
Figure 32

OBLIQUE WING TECHNOLOGY

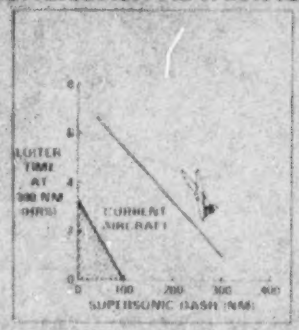
HIGH PERFORMANCE AIRCRAFT



AERODYNAMIC ADVANTAGE



LOITER/DASH ADVANTAGE



NASA

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Figure 33

OBLIQUE WING EXPERIMENTAL PROGRAMS

HIGH PERFORMANCE AIRCRAFT

WIND TUNNEL TESTING

1970-72

REMOTELY PILOTED RESEARCH VEHICLE

1976

AD-1 MANNED FLIGHT

1980

NASA

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NASA HQ RJ85 3843
1-30-85

Figure 34

Mr. LEWIS [presiding]. We will reconvene the hearing.

Mr. Harvey Album and Mr. Barnes McCormick are our next witnesses.

Mr. Album, please proceed with your testimony, sir.

STATEMENTS OF H. HARVEY ALBUM, CHAIRMAN, CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS; AND BARNES W. McCORMICK, VICE CHAIRMAN, CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS

Mr. ALBUM. Yes, sir. My name is Harvey Album, and I am chairman of the Congressional Advisory Committee on Aeronautics. I will be discussing today an assessment of NASA's aeronautics programs and budget for fiscal year 1986.

Now I would like to say a few words about the committee itself because I believe that whenever there is testimony by a group, it's not enough just to say that there was a group that did this, there should always be a question about the qualifications of that group.

The committee was composed of 20 of the Nation's foremost leaders in the field of aeronautics. The members were all selected by a peer group. This committee consisted of vice presidents of engineering, heads of advanced design, directors of technology, heads of laboratories and heads of groups evaluating military and civil aircraft. They represented every sector of aeronautics; the manufacturing industries; the military services, all three of them; the airlines; and academia.

Each member of the committee was selected, not for a particular background in a particular discipline, but rather for having a very broad background. By a broad background I mean a background that would enable them to evaluate competing technologies; they had to be people who would be able to understand the dollars, the payoffs, and the management of R&D programs. We had every sector represented: general aviation, helicopters, military aircraft, fighters, bombers, transport aircraft, trainers—a complete diversity of backgrounds in the group.

The group was convened to provide advice to Congress on aeronautics in general and on NASA programs in specific. Now, to do this we visited NASA's 3 centers involved in aeronautics, and we reviewed 100 independent separate programs. We visited NASA headquarters for a general review of their programs and the overall directions and policies that they were using, and to conduct a second set of specific reviews of selected programs.

In addition, we convened three separate subcommittees to evaluate and to review three particularly important programs.[1] The members on those subcommittees consisted of an additional 17 experts in very specialized fields, in order to be able to come back to the basic committee with the facts involving those programs. The programs that had such special reviews were the oblique wing, the NASA altitude wind tunnel,[2] and the X-wing program.

---

[1] These were a second set of reviews, conducted in detail, for very substantial size NASA programs where the committee either could not reach argument on the priorities of the programs, did not have enough information on them and/or had a low opinions of them based in the initial reviews.

[2] Altitude Wind Tunnel (AWT).

We reviewed and evaluated all of NASA's aeronautical technical programs. In terms of their priorities,[3] we assessed the related funding levels and the manpower in general to determine if they were appropriate for the work and relative to the overall balance of expenditures to best advance aeronautics.

I would like to say at the outset, Mr. Chairman, that the cooperation and the spirit of colleagueship, you might say, between ourselves and the management and engineers at NASA during these reviews, couldn't have been better. They could not have been more open and honest with us. Any differences that we may have are legitimate differences in judgments and in technical opinion.

We completed the evaluation just last Thursday. Worked over the weekend to prepare for the testimony here today, so I don't have finished testimony to read today. I think you have a very rough draft of our report before you, which may have misspellings and things like that. We will have a completed report within the next few weeks to submit for the record.

In going through this, I would really rather do it in a way that I will cover a subject and then elicit questions as we go, rather than to go straight through and have questions at the end. So any time you would like to ask a question, I would feel honored if you would simply ask it at the time.

Let me first cover some general findings. One we have heard very often. It's natural for people in aeronautics to be concerned about progress in our field. The advisory committee believes that by any measure there is really too little emphasis on aeronautics in NASA. This has come up time and again. I know that you're used to hearing this. There has been enough testimony here before this committee and studies done by the administration, including the President's Office of Science and Technology Policy, to clearly identify the enormous importance of aeronautics to the economy, defense, and welfare of our Nation.

Just to make this point a little stronger—let me just cite a few numbers. There were $41 billion in sales in aircraft, agencies and puts in 1983. We recognize the growing importance and enormous effect of space on our Nation and our defense, but this was three times the amount of sales related to space. Seventy percent of these sales related to aeronautics were directly to the Government. In other words, the Government was the buyer. That's part of the reason why there should be concern on the part of the Government about the superiority of aeronautical product. There are 22,000 military aircraft, large and small. I was sort of surprised by that figure. I guess if they were all as powerful as B-1's, we'd be in pretty good shape. The Army, Navy, and Air Force need superior aircraft.

There were $15 billion in aeronautical exports. U.S. airlines took in $38 billion in revenue. They carried the public—people who have an opportunity to experience flight in at least one form—on 300 million trips. There are 700,000 pilots in the United States and 200,000 aircraft. These are the things that make us a great aeronautical power.

---

[3] The importance and appropriateness of NASA conducting the work being performed relative to the need in a national sense.

At the same time, we look at the NASA budget, which supplies the fundamental R&T to this great industry, and we see that it's only 8 percent of the total NASA budget. Now, we're not saying it should be equal, but there certainly seems to be an imbalance here. It's even more significant in this light. Right now, the aeronautics budget is at the lowest level in 15 years, in real terms. Now, either we were doing something wrong before in funding it at higher levels, or we're doing something wrong now. This brings us to the primary question.

Why do we have aeronautics in NASA? It's because we have a system here that works. It's worked well for 70 years. We have a central flow of research and new technology from NASA that doesn't then have to be done by all the different companies in the U.S. and the military services. We have central facilities available in NASA. We have a pool of expert talent that is available to use those facilities for research and also to solve specific problems when they come up. It is an economical and really good management formula that works.

Nobody questions this who really knows anything about the business. And yet, we see it comes up again and again. NASA's role in aeronautics is questioned by people who really don't know very much about this business at all. Now we're faced with kind of a problem, and our group was asked to look at the NASA budget in this light.[4]

What we would like to have done is to come in here with a set of good, solid programs that could put us back on track again. We would like to recommend a lot of things that are really sorely needed to be done. But these would have led to increases in the budget. Therefore, the advisory committee was placed in the difficult position of examining the NASA aeronautics budget under a situation where, to be realistic, we had to try to make our recommendations by trying to hold the current levels.

We did not trade programs back and forth to do that. What we did was to evaluate programs on their merits and to say, "What are the most important things, if we put anything in, that ought to be in there now," and try to keep from putting anything extra in. We looked at the programs that existed in the budget and said, "Are they really, really needed?"

After looking at this budget and looking at NASA's aeronautics programs in detail, I have to say that our view of NASA's activities are just plain positive. There will be a tendency to look only at the differences that we may have with NASA in specific areas, but the plain facts are that after the evaluations, item for item, the overall assessment is very positive. Of the programs we looked at, 78 percent were judged by the group in careful evaluative procedures as being worthy and important, 15 percent were considered very important, and 3 percent were considered extremely important, 2 percent of the programs were considered borderline. We could only find 2 percent, which was two programs, that we considered unsat-

[4] There were reports in the press of OMB cutting the NASA aeronautics budget by 80%, or more, calling it civil aeronautics and saying it can best be done in the private sector. The national budget is under real pressures due to huge deficits.

isfactory. Now, that's a pretty good set of agreements on anything for a group looking at the programs of another organization.

The committee identified changes that should be made in the budget that would total, in absolute terms, roughly $36 million. The amounts to amount to 10 percent of the budget.[5] We recommend increases of about $20 million and decreases of about $16 million and wound up with a net increase of about $3.5 million.

The committee had some very primary recommendations regarding areas of concern that should be addressed in future budgets, if not in this budget. One is the funding for rotorcraft R&T. The downtrending in rotorcraft funding, we believe, is seriously affecting this industry. The downtrend is reflected in the amount of work that is going on and in lack of a few specific facilities needed.

The trend in NASA's work for general aviation you talked about earlier, is really very low. There is a lot of work that is applicable to general aviation in the fundamental work that's going on in NASA—but I won't address that. The specific work for general aviation is only about $11 million, which we think is too low.

The committee believes that a lot more work needs to be done in high-speed aircraft, particularly supersonic aircraft. The advisory committee is seriously concerned that the costs for just the aeronautics facilities are growing out of balance with the funds for the work that's being done in using the facilities and to produce other productive downstream research.[6]

The final concern has to do with computational fluid dynamics. Our committee is very strong on its support of the value of computational fluid dynamics. But here we have a case of a good thing that we believe, in terms of funding, has grown grossly out of balance. I will address that more specifically if you would like me to in response to your questions.

The committee identified only nine exceptions to the budget. I would like to emphasize that we're not satisfied with the level of this aeronautics budget, but we think that in order for the work that goes on to really be meaningful, there should be these nine changes made.

The committee evaluated each program on its merits and the appropriateness of the funding. As I pointed out, we didn't trade them off. If you would like, I can go into each of these programs, and if you want to ask questions on each one, maybe that's a good way to do it.

Mr. GLICKMAN [presiding]. Well, first of all, let me state for the record that what you and your committee have done is in recent years unparalleled. It was done many times during the Second World War, the so-called dollar-a-day man that existed, and I don't think your group even got a dollar a day from the Government. In fact, you didn't even get—your expenses, for the most part, I think were paid for by your respective organizations. And so what you did was unparalleled, and the committee appreciates it, and I think the country will appreciate it in years to come.

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[5] Relative to R&D contract portion of NASA's aeronautics budget.

[6] Relative to its output, status of development, end use, and the funding for other high priority items in the budget.

OBLIQUE WING RESEARCH AIRCRAFT CONCEPT
HIGH PERFORMANCE AIRCRAFT
802
MODIFICATIONS TO NASA F-8 DIGITAL FLY-BY-WIRE RESEARCH AIRCRAFT
NASA
OAST

Figure 35

RSRA/X-WING
ROTORCRAFT
RESEARCH AIRCRAFT CONCEPT
DARPA/NASA
NASA
OAST
NASA HQ RJ85-377(3)
1 30-85

Figure 36

ROTORCRAFT RESEARCH

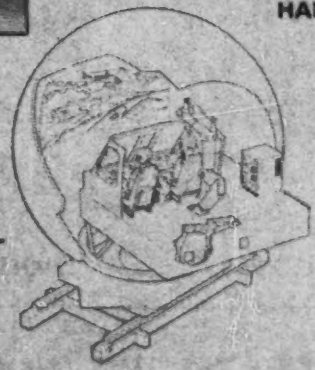
ROTORCRAFT

NOISE

LASER MEASUREMENT OF WAKE FLOW

VIBRATION

FLIGHT DEMONSTRATION OF HIGHER HARMONIC CONTROL



FLIGHT MANAGEMENT

SIMULATOR INVESTIGATIONS OF INTEGRATED SYSTEMS

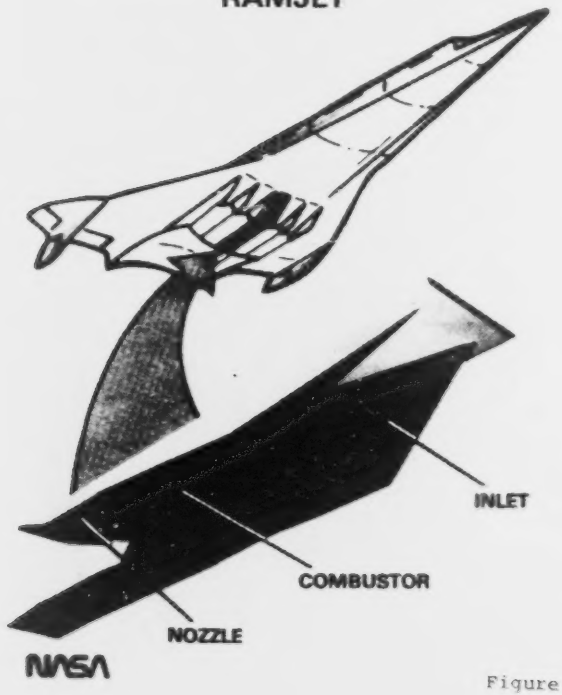
NASA

OAST

Figure 37

HYPERSONIC CRUISE RESEARCH

SUPERSONIC COMBUSTION RAMJET



MACH 5 OVER/UNDER INLET

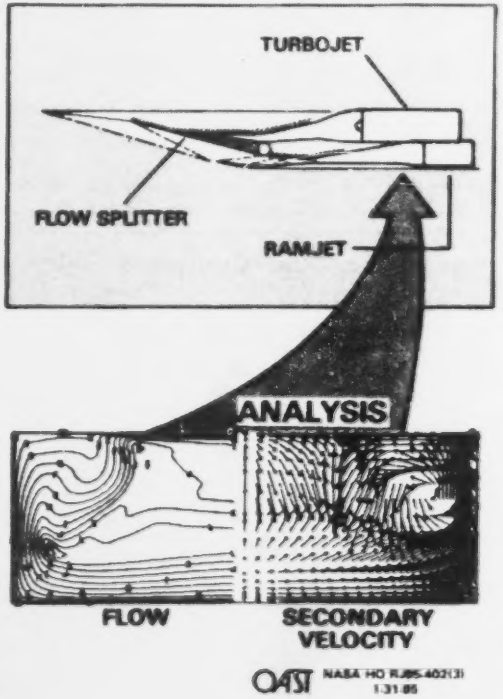


Figure 38

SOURCES OF EXTERNAL ADVICE

AERONAUTICS

- NASA ADVISORY COUNCIL (NAC) – AERONAUTICS ADVISORY COMMITTEE (AAC)
- AERONAUTICS AND SPACE ENGINEERING BOARD (ASEB)
- OFFICE OF SCIENCE AND TECHNOLOGY POLICY (OSTP)
- AERONAUTICS AND ASTRONAUTICS COORDINATING BOARD (AACB) – AEROPANEL
- CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS

Figure 39

I would like just to have you run down for me, if you were making recommendations to us—and I have been looking through this thing, and I will go through it in greater detail, the priority assessment and other kinds of things—list for me those items that you think, if you were in our shoes, that you would want to increase and those items that you would want to decrease and any new items that you think ought to be changed around. You don't need to go into great detail on them, but just basically let us know.

Mr. ALBUM. Well, in the way of increases, we think the rotorcraft systems technology program should be increased from the proposed level by $4 million. This would partially restore the cuts that were made this year. The budget for rotorcraft—this is rotary wing aircraft—exclusive of the X-wing, went from $9.3 million to $5.2 million, and we think that we're recommending a level of $6.7 million to stop this downtrend which has occurred, which is essentially going to zero in a couple of years.[7]

The committee feels that work on turbine engine hot-section technology is extremely important. It was cut from $9.3 million to $5.2 million.

I am sorry, on the generic helicopter work, I have to correct the figures. The funding for systems technology went from $9.2 million to $2.7 million from fiscal year 1985 to fiscal year 1986. I picked off the wrong numbers here.

The turbine engine technology program went from $9.3 million to $5.2 million from fiscal year 1985 to fiscal year 1986. This work is extremely important. It's important not only in terms of the efficiency of engines, but the primary purpose was to extend the life of engine hot-section parts. Airlines spend 50 percent of their engine maintenance costs on the hot section. This is what it essentially boils down to. Engine maintenance costs are 50 percent of all the maintenance costs. So we're dealing here with 25 percent of maintenance costs for aircraft in the airlines area. This is also extremely important, obviously, for military aircraft that use the same kind of engines.

The next item is composite structures systems technology. Now, this was cut from $19 million to zero this year. The committee recommends that there be $7 million in the budget to document the work that has been done to date and to concentrate on some critical areas of thermal plastics and thermal setting rosin systems and also some work on innovative designs. They're not recommending a complete restoration of the program.

Now, in regard to decreases, it's always easy to deal with increases. Everybody feels good about that. Nobody feels good about dealing with decreases.

In the area of computational fluid dynamics, we are not recommending a decrease; we are recommending that it be increased at a level commensurate with the increase in the NASA budget overall, which is about 4 percent. We think that this is growing out of pro-

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[7] This refers to the Rotorcraft Systems Technology Programs. The entire generic budget for rotorcraft, R&T base and systems technology, has declined by about 60 percent since fiscal year 1983. This fact became apparent when we calculated the funds, excluding the X-Wing Program and general facility costs at Ames that are not related to rotorcraft but are included in that budget. Only about $16 million were actually spent on generic R&D rotorcraft in fiscal year 1985, out of a budget figure of over $50 million.

portion to its value relative to other important areas in the budget. In regard to the numerical aerodynamic simulator, NASA proposes that the simulator be developed continuously at about the current rate, as I understand, forever. The committee agrees with that. NASA should be putting in continuously better computers. But the committee believes that the amount of money for this whole area is growing out of balance with everything else being done. The committee recommends that $27 million be spent on the NAS in fiscal year 1986, which is about 20 percent less than the submitted budget. The exact figure should be adjusted commensurate with buying parts of the system. I mean, obviously, you can't buy half a computer, and we were not in a position to weigh each individual item.

Now, let me address what the committee means when we say, "It's growing out of balance." I have heard it said, "Well, it's a matter of feel." That's true. Our group was able to determine from their position roughly how much work there is going on in NASA on computational fluid dynamics and judge what it is worth. But it's more than feel. At this time, there is somewhere on the order of $65 million being spent on the area of developing computational fluid dynamics, including facilities, including research, including use of the current computer facilities.[8] We feel that this is out of balance.

For example, the entire structures program is $28 million.[9] Computing structural responses and aeroelasticity is just as important as computing things in terms of aerodynamics. Furthermore, computational fluid dynamics will be a tool. It's a tool that when it comes into being for practical applications it is going to be extremely useful. We are very highly supportive of that. It will be useful just like a wind tunnel is useful.

Wind tunnels, by the way, are costing NASA at the current time about $45 million.[10] In other words, there is almost $20 million more being spent on computational aerodynamics than is being spent on wind tunnels.[11] And about $16 million of that $45 million is going for supporting military. And that's where we feel the imbalance exists. When you've got a tough budget, to provide the proper balance between good things—all of them good—is a tough judgment.

In the thermal physics budget, the committee recommends that the adaptive wall work be stopped and that the magnetic balance work be stopped. If you have any questions, I can go on with that. We feel that these will not be productive for the costs involved for such tunnels.

But the most important recommendation in terms of facilities has to do with the altitude wind tunnel. The altitude wind tunnel is not in the current cost-of-facilities budget. So one might ask,

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[8] R&D contract, R&PM and cost of facilities.

[9] The entire materials and structures program is about $55 million (R&D contract and R&PM), of this $28 million is about the size of the R&D contract budget.

[10] The fiscal year 1986 expenditures for all of NASA's wind tunnels are about $65 million in total—$45 million in R&D contract funds, $20 million R&PM costs and $22 million in cost of facility funds.

[11] The annual expenditures for NASA's huge complex of 42 wind tunnels are about equal to the annual expenditures for developing computational fluid dynamics, when the cost of wind tunnel tests directly for their agencies are subtracted out.

"Why is the advisory committee concerned about that at all?" We understand that NASA plans to spend $5 million this year in planning this facility. They have 100 people working on it. If you rough out the cost, that amounts to about $12 million a year, just in working toward the facility.

Now, if we didn't know what the facility could do or we were just starting out looking at a new facility, that might be a justifiable expense. But the facility is fairly well defined in terms of what it can do. I might add that our committee first reviewed the basis of this facility as a whole group. We didn't feel we had enough information, so we constituted a subcommittee of experts, and they represented every aeronautics sector—helicopters, rotary/wing helicopters, general aviation, the military, and so forth—and they reviewed the facility for 2 days. Then the overall committee reviewed it again using the findings of the subcommittee.

The facility is scheduled to cost $160 million, and most of the members in our group feel it's going to cost more. It's going to take 7 years to develop. It is a huge facility. The current expenditure rate, as I mentioned, is $12 million, and it's expected to cost $5 million a year once it's in operation. In other words, we're dealing with a very expensive, very large facility.

The question then is, "What do we get from this facility besides a big facility?" The committee is fairly certain that this facility is not suitable for large, full-size aircraft, such as the F-15, as claimed. The problem is what's called tunnel blockage. Tunnel blockage is basically how much of the tunnel section is occupied by the model. If you have a large model and the tunnel walls are too close to it, it affects the data on the model itself. And tunnel blockage for this facility will be, depending upon the model, for the large aircraft—I am talking about F-15 size—will be between 10 to 12 percent. The rule-of-thumb is that the blockage should be no more than 1.5 percent, and you can argue in some cases for 2 percent. But the blockage effects, by our expert group, is fairly certain to exclude these full-size aircraft of this class.

It will not be suitable as claimed for propfans, because you cannot use any more than an 8-foot-size prop in the facility. Propfans are about 12 feet, and it doesn't matter whether it's counter-rotating or whether it is single-rotating. You would not build a scaled-down-size propfan to test in the facility, nor redesign your whole system to have an 8-foot propfan just to test it in this facility.

Mr. GLICKMAN. Harvey, I am going to have to ask you to stop. We are in the second bells of a vote. We are going to be having two votes now. So my guess is we will be back in around 25 minutes.

Mr. ALBUM. OK.

[Recess.]

Mr. GLICKMAN. We apologize. I think this is the end of the roll-call votes. Unfortunately, this is one of the problems with having a hearing when the House is in session. But since we're in session all the time, there's not much we can do.

Harvey, perhaps the pluses and minuses, they are all listed in your report; is that correct?

Mr. ALBUM. That's correct.

Mr. GLICKMAN. OK. Then I am not going to have you go over each of them, but I understand you were talking about the most significant one. You might relate that one.

Mr. ALBUM. Yes. I think this is an extremely important one because of the size of the program, and it may be one of the most important long-term recommendations of our entire testimony. I was listing the limitations of the tunnel first because of the extremely negative vote on this particular facility. I don't think there was any one item that the group had greater consensus on, and the priority of that item is listed on your sheet there.

To continue, the assessment was that the tunnel would not be suitable for large helicopters or rotors as was thought possible. It would not be suitable for large-scale propulsion systems, such as high-bypass-ratio engines. It would provide only a limited increase in propulsion testing for combinations of inlets and nozzles over existing tunnels.

It would be useful for a somewhat expanded flight envelope. It would be useful for small aircraft in terms of testing them in full size. You could test propellers for small aircraft. You could test components of large-size aircraft. You could scale down the size of the larger aircraft and test larger models. And you could do component icing tests in the tunnel.

However, on countering this is the normal procedure of doing scale testing to these same aircraft.[12] In terms of icing tests, it's very common to do icing tests actually in flight.

The net balance of these pluses and minuses is very strongly negative in terms of what you would get from the tunnel as opposed to the enormous costs that will eventually be incurred and the very substantial costs, on the order of $12 million a year, that is currently taking place.

In addition to that, Mr. Chairman, there is the lost opportunity. These 100 people who are working on this tunnel are not normally tunnel designers. They came off R&T activities from other areas. The funds involved also is from the R&T base. The advisory committee felt that they could be more productively used to provide actual R&T for the industry.

The final thing is the question that was brought up earlier regarding the amount of money being spent on icing, which was in the order of $1 million at Lewis. This seems grossly out of line with its importance and the expenditures for this proposed tunnel, of which at least one of its prime purposes is stated to be for icing. The recommended increase of just several hundred thousand dollars and a couple of more people to do research on rotorcraft icing.

Our recommendations were to redirect the people and to redirect the funds currently being spent on the AWT, at NASA's discretion, into the areas of fundamental R&T that could produce worthwhile results in propulsion for the industry.

I might mention, that every segment of the industry was represented on our committee. No one segment supported this tunnel for

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[12] Scaled models currently cannot be used in testing or for research on icing. However, many of the committee members believed that research that would make it possible to reliably use small scale models for icing tests would be far more useful, productive and less costly then expending the energies of 100 research personnel in planning for altitude wind tunnel.

its purposes. And so our recommendation has to be, regretfully, with no joy, as they say, that this effort should be terminated.

We have another program which the committee has recommendations on, which is the oblique wing. Because of my personal situation, which I considered to be a potential conflict of interest on my part, I turned that over to Mr. Barnes McCormick, who is the vice chairman of our committee. He will report on that review. I also was not present for that evaluation.

Mr. McCormick. Well, I also have an unpleasant task of reporting the committee's decision that this program—the budget for this program—should be reconsidered. The committee generally disagrees with the planned full-scale test program utilizing a modified F-8. They feel that the money would be spent on flying an airplane whose design solutions would have extremely low fallout to the industry; that is, that it's a specific configuration.

Further, because there has been a low-speed demonstrator flying testbed flown, model tests, other tests have been done, there don't appear to be any known scale problems of sufficient magnitude to justify the costs involved with modifying and flying the full-scale airplane. Incidentally, the $4.7 million proposed for the program this year looks to be on the optimistic side, according to the committee.

It was felt that the potential benefits in application of the oblique wing can maybe be more efficiently assessed by additional design studies and wind tunnel tests. The committee, therefore, recommends a restructured program of wind tunnel testing and analysis for the oblique wing rather than going to the full-scale flight demonstrator. For this restructured program, we're recommending something in the neighborhood of $1.5 million.

Mr. Album. I would just like to conclude our testimony by pointing out that this committee which you chose to form to advise you is not just another source of advice. It is composed of 20 people, all from different segments of the industry. Now, can you imagine the degree of difficulty that would be involved if we had 20 competing companies trying to agree on how to split up a pocket of money. You probably would not get any agreement unless maybe they tossed a coin or something like that.

These committee members did this, they participated in this, because of their common interest in the advance of American aeronautics. The support I mention for example, for more R&T rotorcraft, we only had three people on our committee for rotorcraft. You would think, "Well, you know, the transport people will vote for transport stuff or they'd caucus or something"—which, incidentally, they weren't allowed to do—"and you wouldn't get agreement on anything," because we had to have a two-thirds vote on everything. The reason they agreed on these things such as more rotorcraft R&T, is because when the facts were on the table, the arguments were compelling enough that there was agreement. So what we are presenting is more than just a matter of a person coming up or two or three people coming up and giving their testimony.

We think the formation of this committee was a wise thing to do. But even beyond that, it is the representation of perhaps—I wouldn't say "for the first time,"—the people who have the great-

est vested interest in the output of NASA in aeronautics because NASA doesn't buy any aircraft have an opportunity to provide their inputs into the programs and into the budgetary process.[13] And for that, on behalf of my committee and every member on it, we thank you.

Mr. GLICKMAN. Do either of you have any questions?

Mr. BOEHLERT. No questions yet, Mr. Chairman.

Mr. GLICKMAN. Oh, I am sorry. Excuse me. Mr. Lewis.

Mr. LEWIS. Mr. Album, I would like to know, with the wind tunnel, with the amount of work that has been done with wind tunnels, what else could be done? I know you've built up several small areas, but I am not sure about the capital areas of the wind tunnel.

Mr. ALBUM. The committee very strongly endorses the modification of a wind tunnel at Langley, which would cost only $8 million to make this tunnel a quiet tunnel for the purpose of assessing noise, for example. Rotorcraft standards for noise imposed by the FAA are really very stringent ones. We do not have a tunnel, any tunnel, in this country that we can use to develop rotorcraft from a standpoint of reducing the noise in order to meet the standard. There is one in Europe. Having this facility would make a enormous difference in our ability, in terms of developing a competitive edge' to meet those standards. In addition, the rotorcraft noise problem is also a very great one for military aircraft, as you can imagine, because you want quiet aircraft, stealthy aircraft, to be able to do those missions.

The tunnel would also be useful for commercial aircraft or aircraft of any types in terms of doing noise measurements. That's an example of an extremely cost-effective step to take. The amount of money, the $8 million, is less than the amount of money being spent in just planning the AWT. The rotorcraft people on our committee said they would rather have that tunnel than the AWT tunnel.

Mr. LEWIS. OK. How about your statement in your report that, "Separate subcommittees conducted independent fact-finding reviews of the three proposed programs," and the final recommendation to terminate the oblique wing flight program, was that the result of a negative assessment by the subcommittee?

Mr. ALBUM. The way in which these subcommittees were formed, sir, they were directed not to give overall recommendations, because we didn't feel that a committee that's formed on a particular subject has the capability of evaluating the value of that item compared to everything else that needs to be done in the budget.

What we asked them to do was to report on the facts in each of these cases to find out what the true circumstances were. I report on some of those findings in my testimony as to what the real facts were. Then the overall committee would weigh these facts, also bringing in their own experiences, and, based on everything, make a judgment.

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[13] The NCAA had a board of directors that performed a similar function for the government—they were the National Advisory Committee for Aeronautics. In addition, NASA has its own advisory committees with some excellent people on it that provide a less direct input into NASA planning.

None of the subcommittee made overall judgments one way or the other. The facts and the pros and cons is essentially what they've tried to determine.

Mr. LEWIS. So what you're telling me is the sheet of paper with the pluses and minuses for the oblique wing from the subcommittee weren't sufficient to convince the committee?

Mr. ALBUM. I would have to ask my cochairman the answer to that, because I wasn't there and I couldn't say that they came from the subcommittee or from the main committee.

Mr. MCCORMICK. Well, my impression is that the chairman, Prof. Al Fuhs, of the subcommittee—who presented the findings of the subcommittee—in a sense, was an advocate for it. But he listed very objectively what the pluses and minuses were. After a long discussion of it in the committee as a whole, we decided that the minuses just simply outweighed the pluses—as far as the full-scale demonstrator was concerned. We're not saying that the oblique wing concept isn't possibly a good one. But the committee doesn't see the need or the reason for going to a full-scale flight demonstrator.

Mr. LEWIS. Well, is your recommendation then to continue research in the oblique wing but not into the full-scale demonstrator?

Mr. MCCORMICK. Yes, sir. The full-scale demonstrator is estimated to cost something like $4.7 million. The committee recommended a much smaller program, at around $1.5 million, to do additional analysis in wind tunnel tests and some design study.

Mr. LEWIS. How much design study has been done with the oblique wing? Are we still talking about doing design studies or continuing design studies, or do we want to get into some good applied research with this $1.5 million or $1-plus million?

Mr. MCCORMICK. Well, I think the fellow with the conflict of interest here could probably answer this question better than I can.

Mr. LEWIS. Conflict of interest——

Mr. MCCORMICK. That's why he has the conflict of interest.

Mr. ALBUM. I didn't say I had one; I said I might have one. [Laughter.]

Mr. LEWIS. OK.

Mr. MCCORMICK. Well, I am personally not that familiar with all the research and design studies that have gone on. I am aware of the RPV studies that were done, the—I have forgotten the designation on it but—the smaller subsonic demonstrator which was flown up to about 200 knots or thereabouts. They checked out control problems. I know that there are some problems. The control system is a little complex because you get control coupling with the oblique wing. As far as looking into specific missions and applications in design studies, I have to say honestly I am not that familiar with it.

Mr. LEWIS. Well, I was just curious if this was part of the negatives or the pluses. I mean you had to have some substantial argument on the committee—well, even the subcommittee didn't come up, apparently, with sufficient recommendation. So I am just concerned that, you know, we just do not stop a program or slow one down considerably if we've done a tremendous amount of work into it, into design and research, and we're almost ready to go to a full-scale testing, that we slow it down because of reasons that may not

be altogether economical as far as the dollars that we put in the program to start with.

Mr. McCormick. Well, I think the point to be made is that it's felt that we know enough about the configuration now to go ahead with the design of a prototype at this point if we wished to, based on what has been done already. So I think it's up to somebody to define a mission for the aircraft and come out with an RFP, and we go ahead if the oblique wing looks like it, fine.

Mr. Lewis. I would like to know what your rationale was, Mr. Album, for your recommendation to cut funds from NAS.

Mr. Album. The rationale was that the amount of money being spent on computational aerodynamics in general was too high in comparison to the rest of the budget. I think I cited the figures in the vicinity of $65 million in comparison to a few others.

The committee felt that since the NAS was a continual development process, it was a judgment call on what that level of effort ought to be, because you're always going to be developing it continuously. You're not trying to develop a specific capability in a specific time period and that's it, then you've got the facility. They said you are always developing in this thing and so it's a judgment call on how much money you want to spend at a given time. Their judgment call is that the amount of money being spent in this area to get essentially what they considered to be—and I think it is—a tool, the same as the wind tunnel is a tool, is too high. In their judgment you could reduce the submitted budget for NAS by 25 percent or 17 percent, there is nothing magic in the exact amount. I don't believe, in the amount that they picked is a solid number. At the same time, they did not go through the rest of the budget and start cutting pockets of money related to computational fluid dynamics either, because the ratings on it were very high. It is just a matter of how much is going into a good thing.

Mr. Lewis. Thank you, Mr. Chairman.

Mr. Glickman. Thank you.

Mr. Packard.

Mr. Packard. I have no questions, Mr. Chairman.

Mr. Glickman. Harvey, let me just ask you two quick questions. How did you minimize conflicts of interest? I think for the record that needs to be disclosed because you all work for companies that may have contracts with NASA and/or the fruits of those contracts in some cases.

Mr. Album. I believe this is an extremely important question whenever you form an advisory committee to advise any segment of government, or your company if you happen to be from a company that calls in a group of that sort.

First of all, every member on the group had a vested interest in the output from NASA. In other words, the R&T that comes out of NASA helps their companies develop products in a competitive mode: a competitive mode against other companies and a competitive mode against the very strong competition coming in at the current time from foreign governments, both in the military and civil area. So they want a high level of output.

But they also have competition between their different segments getting for supporting R&T. Should you have more helicopter programs, more transport programs or whatever? At your direction,

Mr. Chairman, we have a representative grouping from all the different segments of aeronautics, a weighted grouping, and we used voting procedures to such judgments.

So what we have in our committee is not a group that has no vested interests in what is going on, but rather, group with a balance of vested interests. Where you can get agreement will that balance of interests is where you hopefully have the right answer.

The other thing that happens, I might add—to go a little bit beyond your question—is that if they don't have the knowledge to make certain judgments—what happens is that the votes are scattered all over the place. So you get two things at the time you take a vote: first of all, a solid consensus of understanding of what ought to be done when they agree; and second, an indication of whether or not your committee might not have enough knowledge to make the judgment when the votes are scattered.

There was no one selected for this committee who would have a strong personal possible conflict of interest, such as, say if I had bonuses that were dependent upon getting a specific NASA program. I could not be on the committee under those circumstances, or if I was primarily in sales.

The whole criteria that you set up for us, was done in a way to have people making judgments who had strong vested interests in the output of NASA in aeronautics, but not in the contract dollars. There could not be any more than 10 percent of the work under a committee member, such as if you were vice president of engineering, that was under NASA contracts. A member could not be a consultant on NASA contracts.

In running the committee meeting, I usually asked was there anybody in the room who had contracts under the program being considered. If I had a balance on the committee, a guy could have a small contract, and he might be allowed to stay there for his knowledge. He could interact with the committee but he could not vote. Usually he had to leave the room. I had to leave the room three times myself, and Professor McCormick or Professor Fuhs took over.

We always also made sure that we had enough competence on the committee to address the subject. Any individual could remove himself from the committee if he thought he had a personal conflict of interest.

Mr. GLICKMAN. Again, you had secret voting. Right?

Mr. ALBUM. Secret voting is extremely important from two standpoints. First of all, it really helped the judgment process to sit down and vote. We used computers for that. It absolutely puts a focus on the judgment that has to be made and lets you weigh how good that judgment is by the scatter.

The other thing that it does is that sometimes companies have relationships between each other and you never know how the other guy voted. In addition, the individual who is voting could vote his conscience, because his company would never know how he voted.[14]

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[14] People also sometimes worry about their personal and company relationships with NASA. Secret voting allows them some measure of protection in that regard, if there is a censor.

Mr. GLICKMAN. I wonder whether that's applicable in Congress. [Laughter.]

Mr. ALBUM. I think the voters——

Mr. GLICKMAN. Not company——

Mr. ALBUM. The voters might want to know how you vote, sir.

Mr. GLICKMAN. That's the system. They need to know how we vote.

OK. Well, let me ask you just one other question. Propfan, you know—and NASA today testified that they want to continue the propfan. And I think you have indicated that you think you want to continue it. And I would just ask you what is the value of NASA continuing with the propfan when industry is working on the counterrotation concept?

Mr. ALBUM. I think that's an extremely good question that was asked earlier, and I am happy to have the opportunity to respond to it. The basic NASA propfan program started in 1975, with some of the early concepts and early experimental work. It has gone through many technological gates to get to the point where it is now.

The propfan program that we saw laid out for us at Lewis was probably one of the best-planned programs that I personally have ever come across, and I have been involved in quite a number of good ones. It involves not only the basic hardware, but the development of the methodology, the development of the predictive techniques for structures, aerodynamics, and so forth. The tests that are taking place will be able to check those theories. NASA will be able to check the wind tunnel test prediction and so forth. All, or a large portion of that technology is available to future propfans that are developed. In the basic program you have an enormous, well-focused, lined-up, fundamental effort. It's a baseline effort.

The final propfans that are going to be used in industry will be variations from those in the NASA program. There will be improvements on them. As the new technology comes along, a competing technology, such as counterrotation and so forth, you may wind up using that, but you don't keep leaping from horse to horse. The fundamental program has spawned the efforts on counter rotating concepts. There are many problems involved with counterrotation. It's noisier, the fluid interactions are more difficult, the interactions with the structures are more difficult. One of these types of prop fans is going to make it. It may be counterrotating, eventually, but I don't think this is the time to switch horses.[15]

Mr. GLICKMAN. OK. Again, we thank you for the testimony. I have asked NASA to respond to your specific recommendations. I assume they're not going to agree with some of your recommendations. After that response comes in, we're going to want to talk to you again about your response to their response, and we will try to see if we can, before we mark this bill up, try to reach some consensus on some of these things if we can.

We thank you very much.

Mr. ALBUM. Thank you, sir.

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[15] Counterrotating propfan concepts are included in the NASA program (geared and gearless).

Mr. GLICKMAN. Our last witness today is Mr. David Hazen, with the National Research Council, that has issued a report, "Aeronautics Technology Possibilities for 2000."

We are just concerned that we didn't want to be here until 11 o'clock tonight. [Laughter.]

As I told the other witnesses, your entire testimony will appear in the record, so you may want to summarize so we can ask you some questions.

STATEMENT OF DAVID C. HAZEN, NATIONAL RESEARCH COUNCIL, ACCOMPANIED BY ALBERT EVANS, EXECUTIVE DIRECTOR, ASEB

Mr. HAZEN. Mr. Chairman, members of the subcommittee, on behalf of the Aeronautics and Space Engineering Board of the National Research Council, I thank you for the invitation to participate in this hearing. My purpose is to describe to the subcommittee the results of a recent study of the potentials and possibilities for aeronautics by the year 2000, a study that was conducted by the board at NASA's request.

The results of the study I will discuss have recently been published in the report that you have, of which there was a stack over at that table—before the locusts struck. [Laughter.]

I had the privilege of serving as chairman of the workshop on which this report is based. The goal of the effort was to provide the starting point for describing and defining the directions of aeronautical development that could take place if the associated research and technology developments were rigorously pursued.

Now, to attain this view of the future, the board put together a group of roughly 80 experts selected from industry and from academe. We had close liaison with NASA throughout the study. We made a very specific effort to attract to the group younger members of the profession, the "young turks," if you will, in the hopes that we could stimulate some very way-out thinking. In a sense, it was a failure, in that I think the existence of the old fuds like myself inhibited their thinking, and consequently we got out to the horizon but never beyond it.

We organized the group into panels covering seven disciplinary areas, and asked them to project what the possible state of knowledge in each one of those disciplines might be by the year 2000, assuming that the required resources in the form of money, people, and facilities were applied

These projections were then used to identify the types of vehicles that might evolve if those advanced technologies were made available to designers. And again, I have to emphasize that the results of these deliberations are not "pie-in-the-sky," they are really predictions of the rate of development of existing concepts and technologies, given the application of required resources.

The workshop discipline panels were: aerodynamics, propulsion, structures, materials. We grouped one in guidance navigation and cont[illegible]ther in computer and information technology; and [illegible]uman factors.

The information developed by these panels was then integrated by a systems panel into a series of conceptual aeronautical systems.

These preliminary projections, in turn, provided the starting point for a follow-on study that the ASEB is just in the process of completing. Actually, I have a rough draft of the final report on my desk now.

It certainly confirms the predictions made by the systems panel. It simply carried out the designs in greater detail to see if there were some hidden problems that hadn't bubbled to the surface in the quick look-see that we had at the workshop.

Now, I suspect that many people, based largely on the fact that the jet transport configurations and speeds have changed little since their introduction in the 1950's, view aeronautics as a mature field in which future advances will be more on the order of refinements than dramatic leaps, such as the change from the reciprocating engine to the jet. I was delighted to find that the results of the workshop demonstrate that there are still some dramatic leaps ahead. I will try to outline some of these briefly for you today.

There are two pervasive technologies, one of which is, as you all know, advancing at an explosive rate. The fields are computers and materials. They are not generally considered as aeronautically oriented disciplines, but these fields are impacting the traditional areas of aerodynamics, propulsion, structures and control in very fundamental ways, providing a vastly expanded capability in each one of the fields themselves, but perhaps even more significantly, leading to their more complete integration in designs of the future.

For example, developments in computational fluid dynamics, which were discussed at some length here this afternoon, and unobtrusive instrumentation, will provide vastly improved understanding of such fundamental flow phenomena as turbulence, transition, separation, vortex dynamics, and the physics of hypersonic flow. This understanding can be translated into methods of reducing observability in military aircraft and increasing performance of both military and civil machines.

Both viscous and wave drag can be dramatically reduced by active and passive flow control, some of which schemes you heard described today.

Vortex control will lead to improved landing and takeoff performance. Improved understanding of the complex flows involved will lead to helicopter rotor design of improved performance, having lower noise and vibration as well as to improved turboprop operation, higher supersonic propulsion efficiency, ejector augmentation, and hypersonic flight.

Propulsion will benefit from the improved knowledge of aerodynamics through the better design of fans, compressors, and turbines, and improved prediction of the heat transfer for components.

Improved materials should allow operating temperatures of 400 to 600 degrees Fahrenheit higher than currently possible, resulting in higher cycle efficiencies. Additionally, microelectronic developments will provide onboard computational capacity for automated controls, allowing optimal performance.

For conventional turbofan and turboprop engines, these technological advances will provide reduced fuel consumption of 15 to 20 percent for commercial turbofans and perhaps as much as 10 percent for the high-performance military aircraft.

Further gains will appear as higher thrust-to-weight ratios, lower costs, and most importantly, longer engine life. These same technologies will also make possible advanced forms of engines employing such concepts as variable cycles, supersonic flow fans, and ejector thrust augmentation to produce sustained routine and economical flight at altitudes and speeds unattainable today.

Structural design for both the airframe and the engine will keep pace with the steady advances in materials and computational power. Advanced composites utilizing carbon fiber reinforcements will replace aluminum as the primary material in the airframe.

Metal matrix and graphite or carbon-based composites will allow significant improvements in temperature capability and lubrication techniques. Applied to engines, this could translate to more efficient, less costly designs, with as much as a 50-percent increase in thrust-to-weight ratio and a 100-percent increase in life.

It is when discussing controls, however, that I think the true significance of what is happening becomes apparent. Clearly, the increased computational power that will be onboard will permit the development of improved control laws to optimize the performance of conventional airframes and engines.

But even more exciting is the possibility of using distributed sensing and computing power, coupled with adaptive structures which will automatically adapt, or can be controlled to adapt, the airframe configuration for optimal performance throughout the entire flight envelope.

The current practice involves such controls in setting variable wing sweep, diffuser intake, engine tailpipe areas, but what is being projected here couples this with wing camber control and powered aerodynamics to permit higher efficiency and great maneuverability, resulting in what the workshop came to refer to as "bird-like flight."

This is probably a poor term in that it tends to conjure up visions of an airplane flapping through the air, which was not what was intended, but rather that the aircraft would throughout its entire maneuver be configured in such a way that it was flying at the optimum configuration for each element of that maneuver.

A part of the logical extension of this concept is the replacement of conventional stability and control surfaces by engine thrust vectoring, a step that results in smaller, lighter, more efficient airframes. Thus, the conventional areas of aircraft design are blended. The engine contributes to powered aerodynamics and flight control, aerodynamics determines the configuration of the structure.

Because of the highly integrated nature of the aircraft of the future, it is anticipated that virtually no manual control tasks will be performed routinely by the pilots. The principal activities of the crew will be to perform tasks related to cognitive mission management. The unique capability of humans to assimilate and process data and make decisions in the face of uncertainty and ambiguity, especially when dealing with unexpected to less-than-normal events, makes it certain that human operators will continue to play a critical central role in aircraft operations.

Building on the concepts developed by these seven specialist panels, the eighth group addressed the question of what types of aircraft might result from the application of such technology. I find

myself relating particularly to the team that worked on transport aircraft, who took as their guiding principle that it was cruel and unnatural punishment to expect anyone to sit for more than three hours on an airliner regardless of the distance he was traveling. This led, of course, to hypersonic transport designs so one could buzz quickly to Australia at a moment's notice. [Laughter.]

Mr. HAZEN. Although I have not had time to describe all of the findings of the workshop, I have summarized them as an appendix to the written statement which I submit for the record. Much more detail is, of course, available in the report.

Also attached to my written statement is a chart showing the potential improvements in aircraft performance beyond the year 2000, summarized in the report as well.

An important point to keep in mind is that the workshop participants did not predict that these developments would take place, only that they could if the required resources were made available. They made no effort to estimate the magnitude of these resources, nor to establish priorities. That is obviously the next step.

As you know only too well, in the real world of limited resources the knowledge and technology to be pursued must be based on the benefits to be realized and the likelihood of success. Once these choices are made, the R&T program and the necessary facilities can be defined.

One cannot guess how far along the road they charted we may actually get by the year 2000. But I think it's certain that the projections that they made will certainly guide the way. Increasingly, the traditional aeronautical disciplines will overlap and blend. The aircraft of the future, whatever its shape and mission, will be a much more highly automated and integrated machine than any flying today.

That, Mr. Chairman, concludes my statement. I will be happy to answer any questions, as will Mr. Albert Evans, who is the executive director of the ASEB, sitting on my left.

Mr. LEWIS [presiding]. Thank you, Mr. Hazen, for your testimony. Speaking of the cruel and unusual punishment, traveling three hours from here to Australia and what have you, hypersonically, did they address the problem of cruel and unusual punishment of sitting in an airport for 2 or 3 hours waiting for the airplane to get there? [Laughter.]

Mr. HAZEN. No, sir, but they should have. [Laughter.]

Mr. LEWIS. That's beyond scientific reason, I guess.

Mr. HAZEN. Yes, I am afraid so.

Mr. LEWIS. On a scale of 1 to 10 how would you rate NASA's current programs in terms of pursuing the research and technology that you have identified?

Mr. HAZEN. Well, I will have to start by pointing out that at the workshop we did not review NASA's current program in detail, simply made use of that bit of information that related to the areas of interest to the panels. But putting on my professorial hat and falling back on personal biases, I would probably rate what they are doing as a seven or an eight. This is more because the program touches upon all of the points that the workshop felt had to be pursued on a broad scale, but probably should be augmented and focused on the basis of priorities that have yet to be set.

Mr. LEWIS. Did you look at what areas are most efficient?

Mr. HAZEN. Not really. I think my previous comment indicates why I would feel that we aren't at 100 percent. But I feel that I resonate rather strongly with the comments that have been made earlier today.

Mr. LEWIS. Did the group identify any new facilities that would be needed to pursue the research areas identified?

Mr. HAZEN. Each one of the panels was asked to do that just in a broad general way. These were not then reviewed by the overall committee, so they do not form a set of recommendations in the report. However, in the appendices to the report, you will find that each panel did indeed do that. Identified were such things as the large variable density facility for propulsion, a hypersonic facility that would allow testing in the mach numbers 7 to 21 range, thermal test facilities for structures, and a number of other types, undefined in detail; facilities that the panels felt would be necessary to reach the goals that they have stated, not the least of which was a return to NASA's traditional program of research aircraft.

Mr. LEWIS. You indicated that a follow-on study to assess the vehicle types identified in this study has been completed. Can you summarize some of the highlights?

Mr. HAZEN. Well, I think that the benefit of that study is that indeed it took the range of vehicles that we looked at, which went all the way from a super-high-altitude, low-speed, semipermanent platform for either communications or sensor deployment, through commuter aircraft to commercial airliners at the subsonic, supersonic and hypersonic regimes and ended up with a transatmospheric vehicle, which, if you will, would be a follow-on to the space shuttle; a shuttle-type aircraft.

I think the important thing in the follow-on study is that it showed that actually, none of those things are impossible; it did not show up any areas of extreme difficulty that could not be addressed by the types of research recommended and, to a degree, currently being pursued.

Mr. LEWIS. Could you address the question of balance? Do you believe NASA is putting too much emphasis on computational analysis at the expense of experimental research?

Mr. HAZEN. Now, there I am going to have make it very clear that I am not speaking for the workshop or for the committee, but giving you a personal opinion. And that is, no, I feel that computational fluid dynamics is a critically important area, and I am very much in favor of the program NASA is currently pursuing.

Mr. LEWIS. I see. Do you feel they need more facilities or they're investing in facilities at this time?

Mr. HAZEN. Well, I certainly feel that the day of the supercomputer is very much upon us, and that's going to make just a tremendous difference in our understanding of fundamental fluid phenomena.

Mr. LEWIS. But you don't feel they're investing too heavily in it at this point in time?

Mr. HAZEN. No, sir, I do not.

Mr. LEWIS. Thank you.

Mr. Packard.

Mr. PACKARD. Thank you. I don't know whether to call you "Mr. Chairman" or not.

Mr. LEWIS. Sure, you can call me "Mr. Chairman." I am chairing this meeting right now. [Laughter.]

Mr. PACKARD. We minority members wouldn't know how to respond, I suppose, to that.

You mentioned "bird-like flight." I am interested in what your vision of "bird-like flight" is.

Mr. HAZEN. Well, as I tried to explain, this is a highly maneuverable aircraft in which at all times the configuration of the aircraft is modified to produce the optimum conditions throughout the entire maneuver.

For example, if you're a sailplane pilot you know that when you go to make a turn, the mere fact of making the turn places the aircraft in a less efficient flight attitude than when you fly it in straight and level flight.

By being able to modify the configuration of the aircraft, actually changing the camber of the wing in some cases, you could very nearly approach the ideal configuration for that particular maneuver. What should result in the case of a fighter aircraft would be an extremely maneuverable machine.

Mr. PACKARD. I could conjure up ideas of my own on what "bird-like flight" would be, and of course, I understand your explanation, I think. But whatever became of the movement that we see demonstrated occasionally in kind of a showmanship, the ability of an individual to just put on a small piece of equipment and move from here to there? Is there any research being done on that kind of equipment that would lead it to a commercial use or to a competitive use so that individuals could go to and from work and land here and there in the neighborhood or in the city or wherever? Has anything developed, or is there any research being done, to further that concept?

Mr. HAZEN. Only in a desultory way that I am aware of. The military had some interest in this to provide personnel with individual mobility on the battlefield. But I guess the answer to your question would have to be a "no," at least to my knowledge. All of these systems that I am aware of have had a number of deficiencies, the main one being cost, really, when you come right down to it. They could be made controllable and they could be made viable from a performance point of view, but they were all terribly expensive.

Mr. PACKARD. That's "bird-like flight" for me. [Laughter.]

Mr. HAZEN. If you ever heard any of those that were experimented with, it was a very loud, noisy bird.

Mr. PACKARD. Well, I have only seen them on rare occasions. And they're fascinating, but I could appreciate that they may not be very applicable at the time. But that shouldn't preclude the research, perhaps. You never know where research will lead us in those areas.

I am particularly interested, however, in ultrasonic transport for commercial uses. And I am wondering if you feel that this area is receiving a fair share of research money in terms of moving this country forward into being competitive with others in terms of supersonic transport of passengers.

Mr. HAZEN. Again, I will have to make it clear that what I am stating is a personal opinion and not that of the board, because they were very careful to point out that one does not rashly answer that type of question without doing a pretty complete study of the potential viability of such a device.

We are reasonably sure of its technical feasibility, much less certain of its viability as a commercial proposition. There are some indications that it might indeed be so. Based on that, I feel that increased effort could very well be expended in this area. We need more information before we can make the decision whether it is a worthwhile thing to pursue in a major way.

Mr. PACKARD. Is one of the major constraints the environmental constraints on it, or is it cost or something else?

Mr. HAZEN. I would suggest that the major constraint is going to be cost. The environmental concerns I think can be handled.

Mr. PACKARD. Thank you, Mr. Chairman.

Mr. LEWIS. Thank you, Mr. Packard.

Thank you, gentlemen, for your testimony. It is appreciated, and your answers as well.

This committee stands adjourned, subject to the call of the chairman.

[Whereupon, at 4:30 p.m., the subcommittee was adjourned, to reconvene at the call of the Chair.]

APPENDIX

CONGRESSIONAL ADVISORY COMMITTEE
ON AERONAUTICS

REPORT TO CONGRESS

ASSESSMENT OF THE NASA AERONAUTICS BUDGET FOR FY 86

RECOMMENDATIONS

FEBRUARY 28, 1985

Membership
Congressional Advisory Committee on Aeronautics

Chairman

Mr. H. Harvey Allum
Program Manager for Aeronautics
SRI International
333 Ravenswood
Menlo Park, CA 94025
(415)859-4564

Transports

Russell H. Hopps
Vice President & General Manager
Engineering and Development
Lockheed-California Company

Roger Schaufele
Vice President, Engineering
Douglas Aircraft Company
McDonnell Douglas Corporation

Mark E. Kirchner
Director, Engineering Technology
Boeing Commercial Airplane Company

General Aviation

David R. Ellis
Manager, Advanced Design
Cessna Aircraft Company

Ronald D. Neal
Senior Vice President
Program Management & Technology
Gates Learjet Corporation

Helicopters

Edward S. Carter
Chief Scientist
Sikorsky Aircraft

Jan M. Drees
Vice President, Technology
Bell Helicopter Textron, Inc.

High Performance Aircraft

Norman N. Lewin
Deputy Director of Engineering
Grumman Aerospace Corporation

Herbert Sams
Vice President
Engineering Technology
and Advanced Projects
McDonnell Aircraft Company

John B. Walsh
Vice President & Chief Scientist
Boeing Military Airplane Company

Airlines

Richard E. Covkendall
Aircraft Development Manager
United Airlines

Richard J. Linn
Manager, Aircraft Performance & Noise
American Airlines

Propulsion

Gerald L. Brines
Manager, Advanced Engine Programs
Pratt & Whitney Aircraft

Robert C. Hawkins
Vice President & General Manager
Lynn Aircraft Engine Products

University

Barnes W. McCormick
Committee Vice Chairman
Head
Department of Aeronautical Engineering
The Pennsylvania State University

Allen Ruhs
Distinguished Professor
U. S. Naval Post Graduate School

Military

John Chuprun, Jr.
Director, Design Analysis
Deputy for Development & Planning
Air Force Systems Command

Russel G. Perkins, Jr.
Director, Evaluation Division
Naval Air Systems Command

Richard M. Carlson
Director, U. S. Army R&T Labs
U. S. Army Aviation R&D Command

Executive Secretary

D. D. Hicks, Jr., Staff Member
Subcommittee on Transportation, Aviation and Materials
Committee on Science and Technology
U. S. House of Representatives
2321 Rayburn House Office Building
Washington, D. C. 20515
(202) 225-2440

INTRODUCTION

The report presents an assessment of NASA's aeronautics programs and related budgets for FY 86. The views and recommendations presented here represent a consensus of judgments of the Congressional Advisory Committee on Aeronautics.* It is proper to question the qualifications of an advisory committee and the extent of their knowledge of a subject prior to accepting their judgments. The members of this Committee were chosen from among this nation's most outstanding leaders and experts in aeronautics. They were selected to provide a careful balance of backgrounds from every sector of aeronautics: commercial and military transports, general aviation, high speed aircraft such as fighters and bombers, civil and military helicopters, trainers and propulsion systems. The members were selected to provide a representation of backgrounds from every primary segment of the aircraft industry, from the three military services, and from universities. A list of members of the Advisory Committee is given on the first page of the report and resumes of their background may be obtained from the Executive Secretary of the Committee.

The fact that this diverse Committee, composed of leaders from different factions of aeronautics, could reach a high level of accord on the assessments and recommendations presented in this report is highly significant. It indicates that they, as a group, could understand and judge the relative importance of NASA's efforts in different

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* A consensus means that a greater-than-two thirds majority of this Committee shared the opinions presented. Opinions were formulated by a structured assessment process that include closed voting on all points in the testimony. Hence, any given point of view does not necessarily represent the individual opinion of every member of this Committee or their respective organizations.

technical areas. These judgments are even more significant in regard to the potential ultimate benefits of this work because this Committee was basically composed of representatives of all sectors of aeronautics that are the ultimate recipients and users of NASA's output of aeronautical research and technology. In the space program, NASA conducts its own research and development programs, purchases final flight vehicles, and conducts extensive flight operations. However, in aeronautics, NASA is not the end user of the research and technology that it produces; their entire output goes to the manufacturing companies, the military services, and other government agencies. Furthermore, the Committee members had backgrounds from all sectors that conduct aeronautical R&D, which makes them qualified to judge the appropriateness of NASA conducting aeronautical research and technology programs in relation to programs that would naturally be supported, or best conducted, by industry, the military services, or other government agencies. Finally, when the members of a group with diverse and sometimes conpetitive interests can agree among themselves on such wide-ranging assessments and recommendations, it tends to indicate that there is common understanding and support for the stated findings.

However, a committee is not infallible, even when they agree, because a group can be subject to limitations of intellect, natural biases, or a lack of knowledge and understanding of the situation. This Committee was carefully selected to provide a balance of interests on the Committee and strict operating procedures were used to avoid situations in which the Committee as a group would be biased. The Committee reviewed over a hundred NASA aeronautics programs and management

policies and procedures during visits to all three NASA Centers and to NASA Headquarters. Separate ad hoc subcommittees of experts were also formed to separately review and report on three major programs after the Committee could not reach an initial consensus on those programs. The entire Committee also conducted a second review with NASA of every other program that was either not initially well regarded by the Committee or for which there was no initial consensus on the importance of the program. Finally, we realize that there is always the possibility that majority judgments by an expert group (even the two-thirds majority or better that this Committee used) may not always recognize the potential of a radical new innovation. However, within the time available for the assessment, considerable efforts were made to avoid snap judgments or to even make judgments at all in the absence of a sufficient accumulation of information.

The report is divided into three main sections. First, there is an overall assessment of the general direction of NASA's programs and budgets for aeronautics. This section also addresses some general Committee findings and concerns based upon our overall assessment. The second part of the assessment presents an evaluation and recommendations on the specific NASA FY 86 aeronautics budget presented to Congress. This portion of the assessment is presented in the form of tables with priorities for the programs, analyses of the budgets, and recommendations for changes. The second portion of the assessment is complete enough to be separated from the rest of the report and used alone in a brief form. The third and final section of the report presents concluding comments with special concerns of the Committee or

some of its members which were not addressed or were not agreed upon. We should stress that this year our recommendations are made with every attempt to reduce the NASA aeronautics budget to the lowest realistic level in light of the uncommonly severe pressures on the national budget. The fact that we may not have recommended increases in particular programs this year by no means indicates that the Committee was satisfied with the level of effort on those programs.

GENERAL FINDINGS

EMPHASIS ON AERONAUTICS IN NASA

The National Aeronautics and Space Administration has understressed its crucial role in aeronautics. Studies by the White House, as well as extensive evidence and qualified opinion presented in testimony before Congress, have solidly established the importance of aeronautics to the economy, national defense, and welfare of our nation. Recognizing the growing importance of space, it is still a fact that aeronautics -- flight in our atmosphere -- will remain a vital national interest. For example, in 1983 alone, the aerospace industry sales of aircraft engines and parts were $41 billion, which was more than three times that of space-related sales. The government, itself, was the customer for over 70% of the aircraft-related sales for national defense. All three military services rely heavily on aircraft for rapid projection of power. The Air Force, Army, and Navy together have about 22,000 aircraft. The important contribution of aeronautics to our balance of trade is obvious; we export more aeronautical products dollar-wise than any other type of manufacturing goods. The United States exported more than $10 billion in civil aircraft, plus over $5 billion in military aircraft in 1983. U. S. airlines generated over $38 billion in revenues and carried the public on over 300 million trips. Half of these trips were for business purposes. Aviation extended national commerce to and from our small towns and large cities and to every corner of the world. There are more than 700,000 active

pilots and over 200,000 civil aircraft operating in the United States. These are the images of a great aeronautical power. It has been said that aircraft are as central to the economy, defense, and welfare of this nation, in this century, as sailing ships were to the great seafaring nations of earlier centuries.

Nevertheless, the budget submitted by NASA for aeronautics, $632 million, is again only 8 % of NASA's total budget. Of the eight main goals that NASA has established for the agency, only one deals with aeronautics. There are five main operating divisions in NASA's management organization, directly below the Administrator, and every one is engaged in space activities. One has aeronautical research and technology as its prime function along with space research and technology (R&T). Among government organizations, this NASA Office of Aeronautics and Space Technology, its centers, and its people do a good job of managing and conducting aeronautical R&T. They are highly regarded by their peers, worldwide, for the excellence of work that has been produced by their centers. Furthermore, the current NASA Administrator sincerely supports NASA's role in aeronautics. Still, it is a fact that NASA's crucial role in aeronautics is not stressed enough by our government, particularly in regard to funding. The question of why this nation has a central aeronautical R&T organization such as NASA has been answered many times over the last 70 years. It is because this management formula works. For this reason, other countries have copied this same management scheme. NASA/NACA have provided a central source of research expertise producing innovations, methods, and data for all segments of aeronautics in this country. Thus, the research

and generic technology, obtained centrally, is commonly available, economically, to industry and the military services. NASA provides a central organization for acquiring and maintaining major aeronautical facilities that are used for this research and these facilities are also commonly available to other aeronautical organizations in the United States. This management formula has been extremely cost effective because it avoids duplication and provides a central flow of high-leveraged, front-end research that would not otherwise be available. This approach has been a major factor in U. S. dominance in aeronautics for decades.

Yet, the NASA budget for aeronautics stands at the lowest level in 15 years in real terms at the very time when we need it most. This funding crunch, as well as attempts by the Office of Management and Budget (OMB), to cut the NASA aeronautical budget almost in half in 1982 and again this year, is having an extremely negative impact on the productive research output of NASA and on the morale of those engaged in aeronautics in NASA.

OVERALL ASSESSMENT OF PROGRAMS

Overall, NASA is broadly pursuing the correct paths in its aeronautics R&T program. As an organization, it has made great contributions to the field. There is good reason for every NASA engineer and scientist to take pride in what this Committee views as a fine aeronautics program, in spite of its inappropriately low level of emphasis. The Committee reviewed over 100 separate NASA aeronautics programs. We identified only two that the Committee believed should not be in the

budget and only two others that were doubtful. In other words, we believe that roughly 94 % of these programs are necessary and properly belong in the budget. We prioritized the programs by the following designations:

Extremely Important	3%
Very Important	15%
Important	53%
Worthy	25%
Boarderline	2%
Unsatisfactory	2%

The division of programs among these designations is, of course, highly subject to interpretation at the fringes of the various categories. But, there is little doubt that 94% of them are worthwhile programs. The programs had of course all been previously screened by NASA management and most had long histories of productive output.

Still, the Advisory Committee noted substantial deficiencies in the level of funding for certain types of work and the absence of important programs that should have been included in the budget. However, recognizing the extreme budgetary pressures at this time, we decided to evaluate the budget, trying to avoid recommendations that would result in an overall increase over the FY 86 budget submitted this year, if at all possible. There were also problems noted in the balance in funding among program areas. The changes we recommend in this report affect $36.7 million or only about 10% of the aeronautical R&D contract budget. We recommend six programming increases, totaling about $20.2 million, and four programming decreases adding up to $16.6 million. The net result would be an increase of $3.5 million, in the aeronautics R&D contract budget, above that submitted.

The relatively small number of changes recommended for NASA's submitted aeronautics budget reflects well on the overall quality of the aeronautics programs submitted. However, the Committee has a number of serious general concerns about the NASA aeronautics program which were only reflected to a minor degree in the changes we recommend to the FY 86 budget. Real improvements in the areas of concern can only properly be made in a meaningful way in program planning and adjustments in future budgets.

PROGRAM AREAS OF SERIOUS CONCERN

Rotorcraft Systems -- The rotorcraft systems technology budget is trending downward and is simultaneously overburdened by large, single-item expenditures, e.g. the X-Wing concept. Technology for rotorcraft, excluding X-Wing, was seriously cut this year and is projected to go to zero by 1988 or earlier. The NASA budget is out of balance in this regard because rotorcraft have certain problems and research needs that are different than for fixed-wing aircraft. Systems technology for rotorcraft should be maintained at a higher and more constant level of effort than has been the case recently. The general rotorcraft R&D budget, i.e. R&T base plus Systems Technology, has been cut by over 60% since just FY 83, excluding the X-Wing and broad Ames simulator operations charged to that budget. The overall rotorcraft program should be broadened in scope, i.e., less focused.

Future plans in this area should be structured to achieve a more balanced and generic rotorcraft research and technology program. In particular, research aimed at developing new rotorcraft design

methodology is extremely important for both civil and military applications. Rotorcraft noise and vibration are areas that need improvement for the U. S. to attain a competitive edge in its military and commercial products. Research leading to new methods for structural dynamic analysis are essential to control and reduce vibration. The use of new materials and structural designs that are lightweight and vibration resistant need to be synthesized, analyzed, and tested. Research on rotorcraft noise particularly needs to be done for both civil and military applications.

General Aviation -- Fundamental research and technology programs that stress advances in particular areas associated with general aviation should be considerably increased. The NASA program support for these particular types of research and technology is extremely limited in size and scope at an annual level of $11.1 million. The international position of U. S. general aviation is being eroded because technology is being transferred overseas faster than it is being generated here. Furthermore, foreign competitors have dramatically lower labor costs and are being supported in many ways by their governments. We need research and generic technology to obtain new innovations and improvements in our products at a much faster rate than this beleaguered industry can accomplish by itself. The impact of new technology can give this country a strong competitive edge for the larger-sized general aviation aircraft, i.e., turboprop aircraft and business jets. Technology is not a major factor for the smaller general aviation aircraft, except in regard to potential advances for small engines.

High-Speed Aircraft -- NASA should increase the pace of its research for high-speed aircraft in the supersonic range. Here, component research such as improved wing shapes and planforms, inlets and propulsion integration, high-lift methods, advanced materials, flight controls and structures are important. We wish to make clear here that although many aspects of the research and generic technology for supersonic flight apply to a supersonic transport as well as a fighter, supersonic bomber, or a supersonic business jet, NASA's emphasis and orientation on this type of work should not be depicted as supersonic transport technology. Neither the airlines nor the military services are likely to endorse R&T in this area, specifically for transports.

Facilities -- NASA has a large investment in and commitment to support the facilities that are essential to the conduct of aeronautical research. Because facilities are costly to develop, operate, and maintain, NASA management has a difficult task in balancing the expense associated with facility support and that applied to direct R&T efforts. For example, in the extreme, it is possible to spend all of the NASA aeronautics budget developing, modifying, maintaining and manning facilities -- and very little at all on original research for developing new aeronautical innovations for aircraft, even using these facilities. We observe, for instance, that the $16 million facility support cost, for general simulator operations, charged to the rotorcraft budget at the Ames Research Center alone is about one-half of all the R&T funds spent by all NASA centers on rotorcraft. Since extreme facility support costs compete with the resources directly available for original research and technology development, NASA management needs

to devote closer attention to not only acquisition costs but to the downstream affordability considerations relative to the rest of the budget in all decisions associated with the construction of new facilities.

At the same time, the existing wind tunnel facilities are national assets. Prudent management of the existing NASA wind tunnels is critical. These facilities need to be maintained in an operationally ready state. Plans also need to be developed for cost-effective modifications that provide expanded capabilities. For example, a quiet wind tunnel is urgently needed by the U. S. aeronautics industry to provide the means to test aircraft models for noise signatures. This capability is needed to develop quieter helicopters and fixed-wing aircraft. Public acceptance of rotorcraft, in particular, is limited by their high noise levels. Fixed-wing aircraft also need to be quieter to meet community noise standards. The Federal Aviation Administration is formulating more stringent noise criteria for rotorcraft that must be satisfied in their design. In military applications, the noise of rotorcraft has a significant influence on detectability considerations. Currently the only wind tunnel in the world quiet enough to allow scaled model testing is the DNW tunnel in the Netherlands. This facility has proven to be of great value in testing for noise. It has been demonstrated that scale models can be used to predict the noise of full-scale systems with high accuracy. Personnel at the Langley Research Center conducted a study that identified modifications for the 4x7-meter tunnel that could provide a facility similar to the DNW capabilities. The investment needed was estimated to be only $8 million.

The Advisory Committee could clearly understand the need for this modification and the costs were reasonable.

By comparison, we found that NASA is expending about $12 million a year (R&D and R&PM funds) in planning and designing a large Altitude Wind Tunnel (AWT), which is a modification to a tunnel at NASA-Lewis. This facility will cost over $160 million in construction costs beyond the current annual expenditures over a seven-year period. In addition, it would cost over $5 million a year to operate this tunnel. A special subcommittee of experts was formed to assess the added capabilities that this facility would offer. The full Congressional Advisory Committee on Aeronautics critically reviewed the findings by the subcommittee and concluded that this tunnel offered little necessary additional national capability and was far from worth even the current annual the cost. Although proposed in good faith because there are some advantages that this tunnel could offer, NASA must worry about the effectiveness of such excessive facility costs on its R&T mission.

Computational Fluid Dynamics -- The expanding capabilities in computational fluid dynamics is an important and increasingly effective adjunct to the advancements that will influence R&D in aeronautics. The Advisory Committee strongly supports work in this area. However, we are seriously concerned that the portion of NASA's limited resources being devoted to this particular activity is too large. Overall funding (direct and indirect) is out of balance with other high priority R&T activities, such as experimental aerodynamics, structures, and many avenues of innovative R&T needed to directly improve aircraft designs over the next two decades. It appears from our examination of the

budget and NASA's programs that about $65 million per year (R&D, R&PM, and Cost of Facilities) is being expended in total, under various categories, to develop a computational aerodynamics capability. We understand that these costs will grow even greater with time rather than peak after a specific capability is achieved with the National Aerodynamic Simulator (NAS). By comparison, this rate of expenditure is about equal to all the R&D funds plus the R&PM funds being expended by NASA to operate and basically maintain its entire massive complex of 42 existing wind tunnels. If one also includes the cost of facilities for the wind tunnels as well, we find that the annual fund expenditures for developing computational fluid dynamics, as a predictive tool, is still roughly equal to the total rate of expenditure for the wind tunnels, if one subtracts out the portion of NASA's wind tunnel operating costs attributable to tests conducted directly for other agencies and industry.

Computational fluid dynamics is a tool (just like a wind tunnel) to be applied to solve aerodynamic problems. Computational aerodynamics and the National Aerodynamic Simulator will not obviate the need for experimental research on highly conplex and innovative configurations, and it always will be necessary to obtain corroborative experimental data. Furthermore, the capability to handle full complex aircraft and helicopter configurations will be a very long time in coming. The primary factor missing is not just the numerical techniques and the speed and memory of a computer, but primarily the state of knowledge of the equations governing the complex transitional and turbulent flow fields. These equations must be in hand for the

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computer to calculate correct solutions for aircraft. Researchers have been trying to obtain correct governing equations for transitional and turbulent flows for a hundred years. These flows cover the vast portion of aircraft surfaces. The need to maintain a better balance between computational and experimental aerodynamic research at this time is essential to the timely advancement of aeronautical research and technology. Experimentally derived aerodynamic data bases leading to empirical design methodology will continue to be a driving need. When supported by advanced analytic computational methods, a stronger reinforced technology base will result.

Maintenance of a balance in NASA's programs is crucial to a strong aeronautics technology program. The costs associated with computational fluid dynamics are still growing rapidly. The total downstream costs are not yet fully known, but it can be projected that these facility costs will be high and may become an extremely large yearly cost. The total cost, including acquisition and operation, in relation to the actual R&T output from computational fluid dynamics and its facilities and the relative impact on the lost opportunity for crucial useful R&T from other programs is of serious concern.

The Committee believes that these programs can be brought into proper balance with careful planning to achieve the greatest possible effectiveness from the federal investments in NASA to advance American aeronautics.

ASSESSMENT OF THE NASA AERONAUTICS FY 86 PROGRAMS & BUDGETS

ADVISORY COMMITTEE REVIEW

REMOVABLE BUDGET SECTION

GENERAL

The Congressional Advisory Committee on Aeronautics conducted an assessment of NASA programs and proposed budgets for FY 86. The Advisory Committee is composed of aeronautical leaders from every sector of aeronautics, including: the manufacturing industry, airlines, the military services, and the academic community. The members selected for this Committee have expertise and broad knowledge that spans research, technology advancement, development, and operational requirements, as well as all major aeronautical technical disciplines. This group was chosen to provide a careful balance of backgrounds and interests from all segments of aeronautics, including commercial transports, military transports, general aviation, helicopters, military fighters and bombers, trainers, and attack aircraft. The assessment presented in this report is that of knowledgeable leaders from every sector of aeronautics who were able to reach a high level of accord because of their common interest in advancing this nation's aeronautics capabilities.

The Advisory Committee reviewed all of NASA's aeronautics programs and planned budgets during visits to NASA centers and NASA Headquarters. One hundred programs were reviewed. In addition, three separate subcommittees conducted independent, fact-finding reviews of: (1) the planned Altitude Wind Tunnel (AWT) at NASA-Lewis, (2) the X-Wing Program, and (3) the Oblique Wing Program.

This portion of the report has been written so that it can be used separately from the full report. The results of the Committee assessments are given in tables that relate to the budget breakdown submitted to NASA by Congress.

EXPLANATION OF TABLES

This assessment represents a consensus of judgments of the Committee (here, consensus means that a two-thirds majority or more of the Committee were in accord on the judgments presented). Opinions were formulated by a structured assessment process that included closed voting on the priorities, funds, and all major points in the report. Therefore, any given judgment does not necessarily represent the individual opinion of every member of this Committee or their respective organizations. The following is an explanation of each of the columns and the entries in the tables.

Budget Item -- The first column in the table shows the budget items. First, there are summary tables for the major categories in the budget; then, there are more detailed assessment tables with the breakdown for each major category. The individual "discipline" categories in the budget are numbered in the report tables for reference. The tables show evaluations for each of these individual discipline categories identified by NASA in the budget under both R&T Base and Systems Technology programs. Under these discipline categories, also there are assessments of only the programs for which the Committee recommends particular budget constraints or changes in the budget. In general, the Committee expects that the budgets of the other detailed programs

that we reviewed will be consistent with the levels that NASA indicated during presentations to the Committee, but we recognize that there may be a need to reprogram these budgets to some extent.

Submitted Budget -- The second column in the table shows NASA's estimated FY 86 budget submitted to Congress or presented to the Committee as being consistent with that submission. In some cases, NASA's specific figures were not available for FY 86 for detailed programs at the time. The second column is blank in these cases.

Recommended -- The third column in each table shows the specific budget recommended by the Advisory Committee for the program. The Committee estimated the recommended funds from data supplied by NASA and in a few cases from other reliable sources. Often, NASA expenditures for FY 85 or budgets planned for FY 86 were used to make the recommended estimates. The recommended budget for each numbered discipline item reflects the net results of the changes recommended for the detailed programs listed below it. The comments column often provides additional information about the recommended funds.

Priority Assessment -- The Committee voted on program priorities using the subjective verbal descriptions shown at the bottom of each table. The priorities for the numbered discipline item is a weighted average of the priorities for all the detailed programs under that item. The weighting factor was the total annual costs (R&D plus R&PM) for each detailed program. The bracketed numbers in the priority column, below the main priority, show the range of priorities for the detailed programs under the indicated overall discipline. Priorities are shown for detailed programs when there are recommendations for

those programs. At least a two-thirds majority vote of the Committee was required to establish a priority, or the Committee was considered not to have reached a consensus on the priority. Programs with low priorities and for which there were no consenses were assessed twice; first, after initial program reviews with NASA, and then after a second set of program reviews with NASA aimed at clearing up any possible lack of knowledge or misunderstanding on the part of the Committee.

Recommendations, Rationale and Comments -- The last column is self-explanatory.

NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
NASA Aeronautics Budget	632	635.6		This is the lowest NASA budget level for aeronautics in 15 years in real terms; i.e., taking inflation into account. It amounts to only 8% of the total NASA budget and is insufficient in many important areas. Nevertheless, the Congressional Advisory Committee on Aeronautics has made its recommendations here, attempting to remain as close to the submitted budget as possible this year. Our trust is that there will be substantial real growth next year. There must be the research investments necessary to fulfill this nation's national objectives in aeronautics and capitilize on the economic and defense benefits offered by advancements in this crucial field.
Aeronautical R&D (Contract)	354	357.6		
Research & Technology Base	239.3	238.3		
System Technology Programs	114.7	119.3		
Research and Program Management	255	255		The Advisory Committee took into account the man-years devoted to each program in making its assessment of the overall level of effort devoted to it. This was considered in our recommendations. However, the Advisory Committee was informally informed that 130 personnel at NASA-Lewis, formerly working in aeronautical R&T, have been reassigned outside aeronautical work. The people constitute well over 10% of the work force earlier engaged in aeronautical R&T at Lewis. The Committee has not considered these changes in its judgments.
Cost of Facilities	21.999	22.0		

Priority Importance:

90 – Extremely important 70 – Important 50 – Borderline 30 – Minor 10 – Insignificant
80 – Very important 60 – Worthy 40 – Just below entry level 20 – Very minor

NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
RESEARCH AND TECHNOLOGY BASE 1. Fluid and Thermal Physics R&T	48.5	47.1	78 (38-83)	The Committee believes that these programs are very important, and we concur with the overall level of this budget, except for the following noted adjustments and stipulations. Individual programs under this budget item have priorities in the range of 38-83. The weighted average priority for all of the work under this category is 78.
Computational Fluid Dynamics		11.3	80	We recommend an increase of no more than 4%, consistent with NASA's submitted increase for the total aeronautics budget. Work in this area is very important to advancements in aerodynamics, particularly in obtaining a better understanding of the fluid physics. It will also, in time, be of increasing value in the design of aircraft components, such as wings; and, in decades to come, it may be possible to handle entire complex aircraft configurations. It first will be necessary to develop reliable equations to model transition and the turbulent flows that cover most of an aircraft's surfaces. Researchers have been working on this problem for a hundred years and computers must have these equations to use these methods to predict flow fields. Gains in this direction are being made. However, computational aerodynamics will be, even under the best of circumstances, no more than a tool, just as wind tunnels are a tool to predict aerodynamics. The NASA total funding, in this program and elsewhere in the budget, for the development of this research and engineering tool has grown substantially out of balance with the funding for other types of research and basic technology advancements that can be directly applied as innovations in new aircraft designs.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
1. (continued)				
Test Techniques			78	These are very important programs with the exception of the noted work below. The priority given here applies to all programs in this area except for those given below, which have the priorities given.
Magnetic Balance		Zero (-0.6)	38	Magnetic balances have been under development, on and off, for the last 25 years. Even if successful this time, model sizes would have to be too small, i.e., yielding less accurate data for application to flight. Even though certain other sources of error for supported models would be eliminated, the costs of a large enough system for valuable data would be prohibitive. The estimated budget reduction for this item is about $600K based upon 1985 expenditures.
Adaptive Wall		Zero (-0.8)	41	The cost of a useful wind tunnel with adaptive walls would not be cost effective. A small tunnel would result in model sizes that would be too small. For larger models, it would be better simply to conduct tests in a larger existing tunnels. Estimated budget reduction is about $800K based on 1985 expenditures.
2. Applied Aerodynamics R&T	43.7	43.7	76 (54-85)	NASA's overall programs for the development of practical and useful aerodynamics innovations, methods, and data are very important. Individual NASA programs in this budget category have priorities from 54 to 85.

Priority Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
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10 – Insignificant

NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
3. Materials and Structures R&T	28.0	28.0	74 (67-78)	Although we have not recommended increases in materials and structures this year, it is clear that this is an important area of work. Particular NASA program priorities are from 67 to 78. Materials and structures are substantially underfunded in relation to other NASA programs considering the relative importance of the potential for advances in aeronautics. Work is particularly needed, for example, on predictive methods for rotorcraft dynamics, vibration and aeroelasticity. Such work is basic to NASA's mission and would apply to both civil and military helicopters. The Army is doing a great deal in structures, but not in this important fundamental research area.

Priority Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
4. Propulsion and Power R&T	51.0	51.0	79 (29-85)	NASA's propulsion R&T programs are very important to the nation. In the past, these programs have been extremely well coordinated with the military services and with industry. NASA has pursued particularly needed avenues of propulsion R&T contributing, as a central source, to the efforts of more development-oriented organizations. Although we recommend some specific changes under this category, these would be a redistribution of effort rather than a net change in this budget.
Altitude Wind Tunnel (AWT)	5.0	zero	29	We recommend cancelling the large planning effort on the AWT and redirecting the funds and people to fundamental aeronautical propulsion and icing research. Planning for the AWT has gone on for some time and next year would consume about $5 million and 100 man years of effort. Most of the people involved in this effort were diverted from working on propulsion research and component technology advancements. The Committee believes that this facility will cost in excess of the projected acquisition costs of $160 million. Sufficient information is available at this time to evaluate the cost effectiveness of this tunnel. • The AWT will be expensive to operate, exceeding $5 million per year for the facility. • In general, Air Force tunnels and other tunnels offer the same testing capabilities for propulsion systems.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED CHANGE ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
4. (continued)				• The tunnel will not be suitable for testing large-size aircraft/propulsion systems, any prop fans, or helicopter rotors, as claimed, because of the limited size of the test section and substantial blockage effects. This would be true for either propulsion or icing tests. • Propulsion integration testing (e.g., inlets) would only be useful for small-size engines or only the inlet portions. • The facility would be useful for testing reduced scale models, small aircraft, small engines/integration, propellers, and portions or components of larger size aircraft. However, these tests can also be done elsewhere in other tunnels, including accurate small scale testing, or in flight, as is often done for icing research. • Testing for icing of large size aircraft components would be of some value, but is not nearly sufficiently important to justify the large expenditures. There are other icing tunnels, flight testing is considered adequate, and the NASA-Lewis icing research program, at only one-million dollars a year, hardly justifies the additional tunnel. • In total, the limited increase in capabilities offered by the AWT and limited value of the increased national tunnel capacity is not worth the enormous cost.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
5. Information Sciences R&T	22.5	22.5	79 (60-82)	This work is very important, not only for its impact as part of the development of capabilities for computational fluid dynamics, but also for other information processing developments for aeronautics, such as flight control computers. Major portions of these costs are part of the large investment being made in computational fluid dynamics.
6. Controls and Guidance R&T	22.1	22.1	71 (52-74)	We concur. The programs under this budget category are important as a group. The range in priorities for the detailed programs involved are shown in brackets.
7. Human Factors R&T	22.0	22.0	71 (64-74)	We concur. The NASA programs under this catetory are important, as a group, and should be continued. There is only one minor exception. NASA should add a small amount of work within the existing budget to conduct human factors research on integrating the traffic and alert collision avoidance system with existing cockpit procedures, philosophies, and concepts. This would be about a $500,000 annual effort of substantial value.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
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20 – Very minor
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NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
8. Flight Systems R&T	18.3	18.7	75 (67-83)	We concur with this budget and these important programs, with one minor exception.
Rotorcraft Icing		0.75	83	Rotorcraft icing work should be increased to $750K and three man-years. This work is extremely important, in spite of the small funding required; yet, it has been cut in recent years. It must be adequately supported to provide the technology for better certification methods for rotorcraft and to allow the development and use of a low-cost deicing system.
9. Systems Analysis	3.2	3.2	67 (60-72)	We concur.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
SYSTEMS TECHNOLOGY PROGRAM	114.7	119.3		
10. Rotorcraft Systems Technology	20.5	24.5	74 (72-74)	The budget must be increased for helicopter systems. The committee is concerned about the drastic changes and funding reductions occurring in the important area of rotary wing helicopter systems -- where NASA has made such substantial contributions in the past. The specific concerns and recommendations are as follows.
Advanced Rotorcraft Technology	2.7	6.7	75	The funds for this program should be augmented. There has been a general alarming decrease in funding for rotorcraft. The plan seems to be to continue the decrease funding in later years to zero. Funding must be increased in order to maintain a proper balance of work for this important segment of aviation. Specifically, the work on the vibration problem should be continued at Langley. Rotorcraft vibration is the technical problem most likely to wreck development schedules and budgets -- it arises in just about every helicopter development program (military and civil). The Langley program was making good progress in the key area of computational structural dynamics prediction methods to cope with the unique characteristics of helicopter airframes. The work is now only 25% complete and should be continued. The augmentation required to reinstate the Langley effort at the 1985 level is $4 million; 5 man-years should be delegated to the program.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
10. (continued)				
Technology for Next Generation Rotorcraft				
RSRA/X-Wing Aircraft	17.8	17.8	No Comment	The Committee was seriously split on the merits of the basic program; nonetheless, they agreed that it was NASA's responsibility to continue to support its commitment to the test program. Those who questioned the basic program regretted the funds to be so spent in view of the very tight fiscal constraints on NASA's aeronautics program. The program requires re-review next year.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
11. High Performance Aircraft Systems Technology	21.8	20.9	74 (38-80)	We concur with the important work being conducted under this program, with some major exceptions described below.
High Performance Flight Research	9.8	9.8	73 (70-79)	We concur.
Turbine Hot Section Engine Technology	5.2	7.5	80	This is a very important program. The hot section technology program provides important benefits to increase engine life. This is important to both military and civil applications. The military is relying on the output of this basic program to a great extent. About 50% of airline engine maintenance costs are related to the engine hot section, which results in about 25% of total airline maintenance cost. This program has been cut year after year trending continually downward toward zero. The Committee does not consider the reported program stretch out to be as likely as elimination if this trend is not halted.
Ceramics for Turbine Engines	2.1	2.1	65	We concur.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
II. (continued)				
Oblique Wing	4.7	0	38	The Committee strongly disagrees with the planned full-scale test program. Under the current plan, most money would be spent on modification to an airplane whose design solutions would have extremely low fall-out to the industry. Furthermore, there are no known scale problems of sufficient magnitude to justify such airplane costs (which the Committee also believes are very optimistic). The Committee believes that the potential benefits and applications can be better obtained by other than a large-scale manned technology demonstrator aircraft. Additional design studies and wind tunnel tests can provide the required understanding. Such a program is supported by the Committee.
Restructured Oblique Wing Program (added by the Committee)		1.5	60 -	Studies and wind tunnel tests on oblique wing aircraft for high-speed aircraft applications.

Priority/Importance

90 — Extremely important
80 — Very important
70 — Important
60 — Worthy
50 — Borderline
40 — Just below entry level
30 — Minor
20 — Very minor
10 — Insignificant

-33+

NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
12. Subsonic Aircraft Systems Technology	0	7.0	77	
Advanced Composite Structures	0	7.0	77	The Committee considers it is unfortunate that this important program was cancelled under the current budget pressures. NASA has completed work to identify key technology areas in wing and fuselage composite structure applications. The follow-on programs to pursue the technology application in the design and test of generic large components have unfortunately been cancelled and remaining funds are available for reprogramming. The terminated programs should be efficently documented so that the data already obtained can be made useful to industry. The program should be continued to address the key technology areas related to wing and fuselage composite structures. The recommended augmented funding should be delegated to concentrate on thermoplastic and thermosetting composite resin systems, and innovative design concepts, aimed at exploiting the unique features of composite materials, for lower cost fabrication techniques. General aviation is not waiting for the results of this program before going ahead with composite primary structures in production aircraft. However, the technology resulting from this work will be of considerable use to the general aviation industry, particularly in design methodology and knowledge of environmental factors.

Priority Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
13. Advanced Propulsion Systems Technology	44.2	44.2	84	We concur.
Advanced Turboprop Systems	42.0	42.2	84	We concur with the continuation of this extremely important program. Propfan propulsion promises to provide major advances in transport efficiencies for both commercial and military applications.
General Aviation/ Commuter Engine Technology	2.2	2.2	72	We concur. This is an important program that has been under-funded in relation to its potential impact on the industry and the vast number of general aviation operators in this country.
14. Numerical Aerodynamic Simulation (NAS)	28.2	22.7	68	The development of the NAS is a continual process which we support. The expenditure of funds on the numerical aerodynamic simulator will not reduce the need for wind tunnels for testing complete aircraft designs for decades, although it will increase the efficiency of designing aircraft components and increasing our knowledge of flows, within the coming decade.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

CONCLUDING REMARKS

The Congressional Advisory Committee on Aeronautics conducted a comprehensive, highly structured assessment of the priorities and funds for NASA aeronautics programs related to the FY 86 budget. Overall, this assessment of NASA's aeronautics programs is a positive one. We did not concentrate in this report on the extensive number of outstanding and correctly aligned programs, but rather on the areas where changes and improvements are needed. Hence, it is possible to obtain a distorted view of the overall picture from this report, unless this fact is clearly understood. The funding changes we recommend apply to only a small portion of those programs, although they are very important changes. The priorities given relate overall to the potential quality of the work being conducted, the need for the results from NASA, and the cost effectiveness of the programs. We considered the appropriateness of the general levels of funding for each of the programs. However, we gave particular attention to cases in which the Committee recommended specific funds or changes in funding for any program. This year, the Committee did not conduct a comprehensive assessment to identify all the additional programs that should be in a NASA budget in order for NASA to provide the proper level of R&T for aeronautics. Rather, we attempted to recommend the most cost effective, "bare-bones" program that would create the least net changes to the submitted budget.

The Committee recommends some important general changes in NASA program directions and funding levels; some of these aspects were reflected to a minor degree in our advice on the FY 86 budget. Many of

the changes needed would require significant, real increases in NASA funds for aeronautics, and others should be instituted over time in any case. We would like to stress the absolute importance of consistency and stability of support if we are to have effective, long-term research from NASA. New avenues of investigation will arise, work will be completed, and opportunities can be phased into the research program. Reasonable growth can easily be accommodated. But, churning programs, inflicting sharp cuts in funds or manpower, and instituting rapid sweeping shifts in direction are not conducive to achieving major ultimate gains from fundamental research and technology.

There were some aspects that the Committee did not address, due to time limitations. Some members of the Committee expressed concern over major changes, this year, in propulsion program directions and in the organization of the work at NASA-Lewis Research Center. There were also concerns by some members about the division of work into unclear categories (R&T Base vs Systems Technology), as well as the various ways in which utility operating costs are accounted for in the internal planning and budgeting process and in NASA's submission to Congress. Some of the Committee members were interested in considering the basic mission of NASA in aeronautics in regard to the balance of programs being performed. Some members wished to address the division of responsibilities and flexibility of decisions at various management levels.

The Committee, as a group, was concerned about the sources of support (funds and people) on joint projects and for the use of facilities, under the NASA aeronautics program, in cases that clearly fell under the explicit mission of other agencies or of the NASA space

program. In particular, the Committee believed that funds reimbursed to NASA, such as for commercial use of wind tunnels, should not be simply channeled into the U. S. Treasury. The reimbursement or other offsetting support should be used to support NASA aeronautics research efforts that were foregone to provide such support. At the same time, the Committee absolutely is not recommending widespread offset funding for all NASA aeronautics work or facilities support of other agencies engaged in aeronautics, which is part of NASA's basic mission. This is obviously a complex subject and deserves further study before making a final recommendation.

The Committee considered many other issues beyond the recommendations in the report, and a few are worthy of special note. A consensus of the Committee was that additional funds should be devoted specifically to small engines for general aviation aircraft, which is at far too low a level. In a minority opinion, some members of the Committee believed that additional NASA funds should be expended for fundamental hypersonic R&T in view of the Defense Department's interest in transatmospheric vehicles.

At a future date, the Congressional Advisory Committee will address many of the concerns expressed in these concluding remarks. We mention these issues here only to identify some of the limitations of our assessment and no conclusions should be drawn from them.

Questions submitted by Chairman Glickman

QUESTION 1:

Please tabulate the FY 1985 Operating Plan for Aeronautics, explaining any changes from the initial plan (budget request).

ANSWER 1:

The FY 1985 Aeronautics budget total of $342.4 million as submitted in January 1984 has not changed.

The FY 1985 program has been adjusted to accommodate Congressionally directed realignments in the aeronautics program. In an effort to initiate a full-scale flight test of the advanced turboprop propulsion concept in 1987, the research and technology base has been decreased by $10.0 million, and this amount has been applied to the advanced turboprop systems program in advanced propulsion systems technology. One of the major actions required to accomplish this change was a restructuring of the research and technology program at the Lewis Research Center. The program redirection significantly reduced research and technology base emphasis on combustion, fuels, heat transfer and disciplinary component research and focused the remaining research efforts on internal computational fluid mechanics, instrumentation, controls and the technologies for system integration and vehicle applications.

In accordance with other Congressional recommendations, within the research and technology base, $1.2 million has been redirected to support high-speed advanced/short takeoff and vertical landing (A/STOVL) research, and $1.0 million has been redirected to continue work on technology for general aviation propulsion systems which will allow utilization of alternate fuels. The systems technology programs have been realigned to provide $2.5 million from the turbine engine hot section technology program to support research in ceramics for turbine engines.

Detailed explanations of changes from the FY 1985 budget estimate to the FY 1985 current estimate are enclosed.

NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
CONSTRUCTION OF FACILITIES	22	22	80	
Numerical Aerodynamic Simulator Facility	8.2	8.2	80	The building is absolutely essential for the NAS system, regardless of the pace of development of the internal and external equipment and software. Hence, it has a higher priority than the NAS (Item 14).
Modification to 16-Foot Transonic Tunnel	4.9	4.9	80	We concur that this is very important. It is important to retain and expand the productive capability of existing NASA wind tunnels. Relatively small investments in modification to existing tunnels can have a major influence on this nation's testing capability -- when carefully done.
VSTOL 4x7 meter tunnel - modification to a quiet tunnel (committee addition)			85	It is extremely important for efforts to be conducted in FY 86 to indicate a modification program for the 4x7 meter VSTOL tunnel at Langley to convert this tunnel into a quiet wind tunnel for noise signature testing. There is no such tunnel in the United States. The most urgent need for this tunnel is for the development of helicopter rotors to meet FAA standards. If U. S. companies can develop such rotors, it will give them a competitive edge over foreign competition. In addition, noise signatures are extremely important to military helicopters. This tunnel will be useful for commercial and military fixed wing aircraft. The cost of the modification is estimated to be only $8 million, which will yield a high payoff for a modest investment. This should be placed in the FY 87 Construction of Facilities budget.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

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NASA AERONAUTICS BUDGET FOR FY86

CONGRESSIONAL ADVISORY COMMITTEE ON AERONAUTICS ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
Rehabilitation and Modification	4.3*	4.3	80	We concur. It is very important to retain and expand the productive capability of existing NASA wind tunnels. Relatively small investments in modification to existing tunnels can have a major influence on this nation's testing capability -- when carefully done.
Ames/Dryden	1.6*	1.6		
Langley	1.8*	1.8		
Lewis	0.9*	0.9		
Repairs	4.7*	4.7	80	We concur. It is very important to retain and expand the productive capability of existing NASA wind tunnels. Relatively small investments in modification to existing tunnels can have a major influence on this nation's testing capability -- when carefully done.
Ames	1.6*	1.6		
Langley	1.1*	1.1		
Lewis	2.0*	2.0		

* Advisory Committee estimates taken from "NASA Budget Estimates, FY 86, Vol. II, Construction of Facilities"

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
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30 – Minor
20 – Very minor
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FY 1985 AERONAUTICS OPERATING PLAN
BUDGET VS. CURRENT PLAN

	(Dollars in Thousands)		
	FY 1985 Budget Estimate	Change	FY 1985 Current Estimate
AERONAUTICAL RESEARCH AND TECHNOLOGY.....	342,400	-0-	342,400
Research and Technology Base.....	233,300	-10,000	223,300

The research and technology base was reduced by $10.0 million to provide funding for efforts in the advanced turboprop program leading to an initial flight test in 1987, in accordance with Congressional direction. In addition, several realignments have been made within the research and technology base to fund high priority program requirements.

Fluid and Thermal Physics Research and Technology.....	49,000	-5,000	44,000

This program has been decreased by a total of $5.0 million, primarily in the areas of combustion, fuels, and heat transfer, as a portion of a general reduction to support the acceleration of the advanced turboprop program. This action was part of the restructuring of the aeronautics research program at the Lewis Research Center.

Applied Aerodynamics Research and Technology.....	42,500	-500	42,000

The applied aerodynamics program was decreased by $0.5 million as a portion of a general reduction to support the acceleration of the advanced turboprop program.

	(Dollars in Thousands)		
	FY 1985 Budget Estimate	Change	FY 1985 Current Estimate
Materials and Structures Research and Technology.....	25,800	+2,000	27,800

The materials and structures research and technology program was increased by $2.0 million. This is the result of the transfer of the integrated program for aerospace vehicle design from the information sciences research and technology program to materials and structures and the realignment of this effort for the initiation of research in computational structural mechanics.

Propulsion and Power Research and Technology.....	30,500	-1,800	28,700

The propulsion and power research and technology program was reduced by $1.8 million. The program at the Lewis Research Center has been restructured to reduce disciplinary component research and to emphasize technologies for integrated systems and specific vehicle applications. The net effect is a $3.0 million reduction to support the acceleration of the advanced turboprop program, offset by an increase of $1.2 million for advanced/short takeoff and vertical landing (A/STOVL) activities. Within this budget line item, $1.0 million has been redirected to continue work on technology for general aviation propulsion systems which will allow utilization of alternate fuels.

Information Sciences Research and Technology.....	23,800	-2,700	21,100

The information sciences research and technology program was decreased by a total of $2.7 million, which included the transfer of the integrated program for aerospace vehicle design to materials and structures research and technology and a portion of a general reduction to support the acceleration of the advanced turboprop program.

Controls and Guidance Research and Technology.....	21,500	-1,000	20,500

This program was decreased by $1.0 million in the integrated propulsion/controls research area, and the funding has been redirected within the aeronautics program primarily to support A/STOVL efforts and the acceleration of the advanced turboprop program.

QUESTION 2:

Please tabulate for fiscal years 1984 through 1990 runout costs of the current aeronautics program (broken out by standard budget sub-line items as presented in the R&D budget book, including R&T Base programs). Also, please provide figures for one budget level below these sub-line items.

ANSWER 2:

See the enclosed table.

QUESTION 3:

Please tabulate, for fiscal year 1984 through 1990, runout costs of the current aeronautics program (broken out in the following categories: Subsonic, G/A, Rotorcraft, STOVL, Commuter Aircraft, High Performance, Supersonic, Hypersonic, and Generic R&T). Also, to permit relating this to the standard budget sublines, please provide a further breakout, for each category, showing funds included in the R&T Base, and the various Systems Technology Programs identified by budget sub-line item and further identified by program (e.g., Advanced Propulsion Systems Technology under Subsonic and ATP under Advanced Propulsion Systems Technology).

ANSWER 3:

The enclosed table contains the runout of the aeronautics program (FY 1984 through FY 1990) in the following categories:

General Aviation
Transport
Supersonic
Hypersonic
STOVL
Rotorcraft
Generic

By way of explanation, the Subsonic program is the combination of the General Aviation and Transport categories. Commuter aircraft are included in the General Aviation category. High Performance aircraft programs are represented by the sum of the Supersonic, Hypersonic, and STOVL categories in the table.

	(Dollars in Thousands)		
	FY 1985 Budget Estimate	Change	FY 1985 Current Estimate
Human Factors Research and Technology.....	21,300	-1,000	20,300

The $1.0 million decrease in this program primarily reflects the elimination of the simulation science program, and the major portion of the funding was redirected to support the acceleration of the advanced turboprop program.

Flight Systems Research and Technology.....	16,300	-0-	16,300

The funding for this activity has not changed; however, $0.5 million was transferred to this program for convertible engine research from rotorcraft systems technology, and $0.5 million was transferred to the high-performance aircraft systems technology line to meet priority program requirements.

Systems Analysis.....	2,600	-0-	2,600
Systems Technology Programs.....	109,100	+10,000	119,100

This increase of $10.0 million reflects redirection of funding from the research and technology base to support the accelerated advanced turboprop program in accordance with Congressional direction.

Rotorcraft Systems Technology.....	26,500	-500	26,000

Funding amounting to $0.5 million was transferred from advanced rotorcraft to the research and technology base for flight systems research and technology to support priority convertible engine research requirements.

	(Dollars in Thousands) FY 1985 Budget Estimate	Change	FY 1985 Current Estimate
High-Performance Aircraft Systems Technology.....	21,000	+500	21,500

Precursor oblique wing activities within the high-performance flight research program were augmented by a transfer of $0.5 million from the flight systems research and technology base program. In addition, in response to Congressional recommendations, $2.5 million was internally realigned to augment ceramics for turbine engines. This was accommodated through a reduction in the turbine engine hot section technology program.

Subsonic Aircraft Systems Technology.....	19,000	-0-	19,000
Advanced Propulsion Systems Technology.....	16,100	+10,000	26,100

This program was increased by realignment of $10.0 million to the advanced turboprop program from the research and technology base program for efforts leading to an initial flight test in 1987, as directed by Congress.

Numerical Aerodynamic Simulation.....	26,500	-0-	26,500

FY 1986 CONGRESSIONAL BUDGET
(Real Year $,M)

	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
AERONAUTICS RESEARCH & TECHNOLOGY	315.3	342.4	354.0	366.5	355.6	349.4	356.7
RESEARCH AND TECHNOLOGY BASE	228.5	223.3	239.3	260.5	275.6	287.6	298.0
FLUID & THERMAL PHYSICS R&T	43.4	44.0	48.5	52.8	55.9	58.3	60.4
APPLIED AERODYNAMICS R&T	42.3	42.0	43.7	47.6	50.4	52.6	54.5
MATERIALS & STRUCTURES R&T	23.9	27.8	28.0	30.5	32.3	33.7	34.9
PROPULSION & POWER R&T	23.5	28.7	31.0	33.7	35.6	37.2	38.5
INFORMATION SCIENCES R&T	35.0	21.1	22.5	24.5	25.9	27.0	28.0
CONTROLS & GUIDANCE R&T	19.6	20.5	22.1	24.1	25.5	26.6	27.6
HUMAN FACTORS R&T	19.4	20.3	22.0	23.9	25.3	26.4	27.4
FLIGHT SYSTEMS R&T	17.5	16.3	18.3	19.9	21.0	21.9	22.7
SYSTEMS ANALYSIS	3.9	2.6	3.2	3.5	3.7	3.9	4.0
SYSTEMS TECHNOLOGY PROGRAMS	86.8	119.1	114.7	106.0	80.0	61.8	58.7
ROTORCRAFT SYSTEMS TECHNOLOGY	27.9	26.0	20.5	4.6	-	-	-
GUIDANCE & NAVIGATION	1.6	-	-	-	-	-	-
RSRA FLIGHT RESEARCH/ROTORS	3.3	-	-	-	-	-	-
ADVANCED ROTORCRAFT TECHNOLOGY	14.7	9.7	2.7	2.0	-	-	-
TECH. FOR NEXT GENERATION ROTORCRAFT	8.3	16.3	17.8	2.6	-	-	-
HIGH-PERFORMANCE AIRCRAFT SYSTEMS TECH.	19.9	21.5	21.8	26.0	20.8	16.8	12.1
HIGH-PERFORMANCE FLIGHT RESEARCH	8.7	9.7	9.8	10.4	11.0	11.7	12.1
TURBINE ENGINE HOT SECTION TECH.	11.2	9.3	5.2	5.0	3.8	3.5	-
CERAMICS FOR TURBINE ENGINES	-	2.5	2.1	2.2	2.4	-	-
OBLIQUE WING TECHNOLOGY	-	-	4.7	8.4	3.6	1.6	-
SUBSONIC AIRCRAFT SYSTEMS TECH.	5.0	19.0	-	-	-	-	-
ADVANCED COMPOSITE STRUCTURES TECH.	5.0	19.0	-	-	-	-	-

	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
ADVANCED PROPULSION SYSTEMS TECH.	17.0	26.1	44.2	45.4	32.5	16.7	17.3
ADVANCED TURBOPROP SYSTEMS	15.0	24.0	42.0	43.0	30.0	14.0	14.5
GENERAL AVIATION/COMMUTER ENG. TECH.	2.0	2.1	2.2	2.4	2.5	2.7	2.8
NUMERICAL AERODYNAMIC SIMULATION	17.0	26.5	28.2	30.0	26.7	28.3	29.3
NUMERICAL AERODYNAMIC SIMULATION	17.0	26.5	28.2	30.0	26.7	28.3	29.3

AERONAUTICAL RESEARCH AND TECHNOLOGY
SPECIAL ANALYSIS
(Real Year $ in Millions)

	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
GENERAL AVIATION AIRCRAFT	10.0	10.3	11.1	12.1	12.7	13.3	13.8
RESEARCH & TECHNOLOGY BASE	8.0	8.2	8.9	9.7	10.2	10.6	11.0
FLUID & THERMAL PHYSICS RESEARCH & TECHNOLOGY	1.4	1.5	1.6	1.7	1.8	1.9	2.0
APPLIED AERODYNAMICS RESEARCH & TECHNOLOGY	2.1	2.1	2.2	2.4	2.5	2.6	2.7
PROPULSION & POWER RESEARCH & TECHNOLOGY	1.6	1.9	2.1	2.3	2.4	2.5	2.6
CONTROLS & GUIDANCE RESEARCH & TECHNOLOGY	0.4	0.4	0.4	0.4	0.5	0.5	0.5
HUMAN FACTORS RESEARCH & TECHNOLOGY	1.5	1.6	1.7	1.9	2.0	2.1	2.2
FLIGHT SYSTEMS RESEARCH & TECHNOLOGY	0.6	0.5	0.6	0.7	0.7	0.7	0.7
SYSTEMS ANALYSIS	0.4	0.2	0.3	0.3	0.3	0.3	0.3
ADVANCED PROPULSION SYSTEMS TECHNOLOGY	2.0	2.1	2.2	2.4	2.5	2.7	2.8
GENERAL AVIATION/COMMUTER ENGINE TECHNOLOGY	2.0	2.1	2.2	2.4	2.5	2.7	2.8
TRANSPORT AIRCRAFT	45.8	69.2	70.0	73.6	62.4	47.8	49.5
RESEARCH & TECHNOLOGY BASE	25.8	26.2	28.0	30.6	32.4	33.8	35.0
FLUID & THERMAL PHYSICS RESEARCH & TECHNOLOGY	4.0	4.1	4.5	4.9	5.2	5.4	5.6
APPLIED AERODYNAMICS RESEARCH & TECHNOLOGY	3.5	3.5	3.6	3.9	4.1	4.3	4.5
MATERIALS & STRUCTURES RESEARCH & TECHNOLOGY	1.7	2.0	2.0	2.2	2.3	2.4	2.5
INFORMATION SCIENCES RESEARCH & TECHNOLOGY	4.0	3.8	4.1	4.5	4.8	5.0	5.2
CONTROLS & GUIDANCE RESEARCH & TECHNOLOGY	7.8	8.2	8.8	9.6	10.2	10.6	11.0
HUMAN FACTORS RESEARCH & TECHNOLOGY	2.9	3.1	3.3	3.6	3.8	4.0	4.1
FLIGHT SYSTEMS RESEARCH & TECHNOLOGY	0.9	0.8	0.9	1.0	1.1	1.1	1.1
SYSTEMS ANALYSIS	1.0	0.7	0.8	0.9	0.9	1.0	1.0

QUESTION 4:

Please provide a tabulation for each large development project where total anticipated costs exceed $50 million, showing:

a. Original estimated date of completion and cost;
b. Estimated date and cost of completion furnished to the Subcommittee last year;
c. Current estimates;
d. Reasons for change from last year.

ANSWER 4:

See the enclosed table.

QUESTION 5:

Please provide quantitative data that traces the development of the FY 1986 budget request. Specifically, please show initial and final OAST recommendations, the submission to OMB and the request to Congress for new initiatives.

ANSWER 5:

See the enclosed table.

	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
ADVANCED PROPULSION SYSTEMS TECHNOLOGY	15.0	24.0	42.0	43.0	30.0	14.0	14.5
ADVANCED TURBOPROP SYSTEMS	15.0	24.0	42.0	43.0	30.0	14.0	14.5
SUBSONIC AIRCRAFT SYSTEMS TECHNOLOGY	5.0	19.0	-	-	-	-	-
ADVANCED COMPOSITE STRUCTURES TECH.	5.0	19.0	-	-	-	-	-
SUPERSONIC AIRCRAFT	70.7	73.3	77.0	85.9	84.4	83.2	80.9
RESEARCH & TECHNOLOGY BASE	51.7	52.8	56.2	61.0	64.7	67.6	70.0
FLUID & THERMAL PHYSICS RESEARCH & TECHNOLOGY	1.5	1.5	1.7	1.8	1.9	2.0	2.1
APPLIED AERODYNAMICS RESEARCH & TECHNOLOGY	21.1	21.0	21.8	23.7	25.1	26.4	27.1
MATERIALS & STRUCTURES RESEARCH & TECHNOLOGY	4.5	5.3	5.3	5.7	6.0	6.4	6.6
PROPULSION & POWER RESEARCH & TECHNOLOGY	6.4	7.9	8.5	9.3	9.8	10.2	10.6
INFORMATION SCIENCES RESEARCH & TECHNOLOGY	4.0	3.8	4.1	4.5	4.8	5.0	5.2
CONTROLS & GUIDANCE RESEARCH & TECHNOLOGY	2.8	2.9	3.1	3.4	3.6	3.7	3.8
FLIGHT SYSTEMS RESEARCH & TECHNOLOGY	10.5	9.8	11.0	11.8	12.6	13.1	13.7
SYSTEMS ANALYSIS	0.9	0.6	0.7	0.8	0.9	0.8	0.9
HIGH-PERFORMANCE AIRCRAFT SYSTEMS TECHNOLOGY	19.0	20.5	20.8	24.9	19.7	15.6	10.9
HIGH-PERFORMANCE FLIGHT RESEARCH	7.8	8.7	8.8	9.3	9.9	10.5	10.9
TURBINE ENGINE HOT SECTION TECHNOLOGY	11.2	9.3	5.2	5.0	3.8	3.5	-
CERAMICS FOR TURBINE ENGINES	-	2.5	2.1	2.2	2.4	-	-
OBLIQUE WING TECHNOLOGY	-	-	4.7	8.4	3.6	1.6	-
HYPERSONIC AIRCRAFT	4.5	5.2	5.6	6.1	6.4	6.7	7.0
RESEARCH & TECHNOLOGY BASE	4.5	5.2	5.6	6.1	6.4	6.7	7.0
FLUID & THERMAL PHYSICS RESEARCH & TECHNOLOGY	0.4	0.4	0.4	0.4	0.5	0.5	0.5
APPLIED AERODYNAMICS RESEARCH & TECHNOLOGY	0.1	0.1	0.1	0.1	0.1	0.1	0.1
MATERIALS & STRUCTURES RESEARCH & TECHNOLOGY	0.3	0.4	0.4	0.4	0.5	0.5	0.5
PROPULSION & POWER RESEARCH & TECHNOLOGY	3.3	4.1	4.4	4.9	5.0	5.2	5.5
SYSTEMS ANALYSIS	0.4	0.2	0.3	0.3	0.3	0.4	0.4

	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
STOVL (INCLUDES STOL AND V/STOL)	4.9	5.2	5.5	6.0	6.3	6.6	6.8
RESEARCH & TECHNOLOGY BASE	4.0	4.2	4.5	4.9	5.2	5.4	5.6
FLUID & THERMAL PHYSICS RESEARCH & TECHNOLOGY	0.9	0.9	1.0	1.1	1.2	1.3	1.3
APPLIED AERODYNAMICS RESEARCH & TECHNOLOGY	2.1	2.1	2.2	2.4	2.5	2.6	2.7
PROPULSION & POWER RESEARCH & TECHNOLOGY	0.9	1.1	1.2	1.3	1.4	1.4	1.5
CONTROLS & GUIDANCE RESEARCH & TECHNOLOGY	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HIGH PERFORMANCE AIRCRAFT SYSTEMS TECHNOLOGY	0.9	1.0	1.0	1.1	1.1	1.2	1.2
HIGH-PERFORMANCE FLIGHT RESEARCH	0.9	1.0	1.0	1.1	1.1	1.2	1.2
ROTORCRAFT	57.2	55.2	52.0	38.9	36.4	37.9	39.2
RESEARCH & TECHNOLOGY BASE	29.3	29.2	31.5	34.3	36.4	37.9	39.2
FLUID & THERMAL PHYSICS RESEARCH & TECHNOLOGY	4.1	4.2	4.6	5.0	5.3	5.5	5.7
APPLIED AERODYNAMICS RESEARCH & TECHNOLOGY	9.7	9.6	10.0	10.9	11.6	12.0	12.4
PROPULSION & POWER RESEARCH & TECHNOLOGY	1.1	1.4	1.5	1.6	1.7	1.8	1.9
INFORMATION SCIENCES RESEARCH & TECHNOLOGY	3.5	3.4	3.6	3.9	4.1	4.4	4.6
CONTROLS & GUIDANCE RESEARCH & TECHNOLOGY	0.9	0.9	1.0	1.1	1.2	1.2	1.2
HUMAN FACTORS RESEARCH & TECHNOLOGY	4.1	4.3	4.7	5.1	5.5	5.6	5.8
FLIGHT SYSTEMS RESEARCH & TECHNOLOGY	5.5	5.2	5.8	6.4	6.6	7.0	7.2
SYSTEMS ANALYSIS	0.4	0.2	0.3	0.3	0.4	0.4	0.4
ROTORCRAFT SYSTEMS TECHNOLOGY	27.9	26.0	20.5	4.6	-	-	-
GUIDANCE & NAVIGATION	1.6	-	-	-	-	-	-
RSRA FLIGHT RESEARCH/ROTORS	3.3	-	-	-	-	-	-
ADVANCED ROTORCRAFT TECHNOLOGY	14.7	9.7	2.7	2.0	-	-	-
TECHNOLOGY FOR NEXT GENERATION ROTORCRAFT	8.3	16.3	17.8	2.6	-	-	-

	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
GENERIC	122.2	124.0	132.8	143.9	147.0	153.9	159.5
RESEARCH & TECHNOLOGY BASE	105.2	97.5	104.6	113.9	120.3	125.6	130.2
FLUID & THERMAL PHYSICS RESEARCH & TECHNOLOGY	31.1	31.4	34.7	37.9	40.0	41.7	43.2
APPLIED AERODYNAMICS RESEARCH & TECHNOLOGY	3.7	3.6	3.8	4.2	4.5	4.6	5.0
MATERIALS & STRUCTURES RESEARCH & TECHNOLOGY	17.4	20.1	20.3	22.2	23.5	24.4	25.3
PROPULSION & POWER RESEARCH & TECHNOLOGY	10.2	12.3	13.3	14.3	15.3	16.1	16.4
INFORMATION SCIENCES RESEARCH & TECHNOLOGY	23.5	10.1	10.7	11.6	12.2	12.6	13.0
CONTROLS & GUIDANCE RESEARCH & TECHNOLOGY	7.6	8.0	8.7	9.5	9.9	10.5	11.0
HUMAN FACTORS RESEARCH & TECHNOLOGY	10.9	11.3	12.3	13.3	14.0	14.7	15.3
SYSTEMS ANALYSIS	0.8	0.7	0.8	0.9	0.9	1.0	1.0
NUMERICAL AERODYNAMIC SIMULATION	17.0	26.5	28.2	30.0	26.7	28.3	29.3
NUMERICAL AERODYNAMIC SIMULATION	17.0	26.5	28.2	30.0	26.7	28.3	29.3
TOTAL.....	315.3	342.4	354.0	366.5	355.6	349.4	356.7

MAJOR AERONAUTICS PROGRAMS: TOTAL COST/SCHEDULE CHRONOLOGY
($ in Millions)

	ORIG. EST.		JAN. 1984 EST.		CURRENT EST.		
	DATE OF COMPLETION	COST	DATE OF COMPLETION	COST	DATE OF COMPLETION	COST	REASON FOR CHANGE FROM LAST YEAR
Advanced Composite Structures Tech.	1989	107.5	1989	107.4	---	---	Program terminating. Cost through FY 1985 is $24.0 million.

CHRONOLOGY OF FY 1986 AERONAUTICS BUDGET
($ in Millions)

	OAST RECOMMENDATION	SUBMISSION TO OMB	SUBMISSION TO CONGRESS
ONGOING.....	391.8	391.2	354.0
R&T BASE	247.1	246.5	239.3
SYSTEMS TECHNOLOGY	144.7	144.7	114.7
Rotorcraft Systems Technology	20.5	20.5	20.5
High-Performance Aircraft Systems Technology	25.9	25.9	21.8
Subsonic Aircraft Systems Technology	25.9	25.9	---
Advanced Propulsion Systems Technology	44.2	44.2	44.2
Numerical Aerodynamic Simulation	28.2	28.2	28.2
BASELINE ADJUSTMENTS (included above)	(38.0)	(32.7)	(32.7)
Oblique Wing Technology	(4.7)	(4.7)	(4.7)
Advanced Turboprop Systems	(28.0)	(28.0)	(28.0)
High-Speed Aircraft Technology	(5.3)	-	-
AUGMENTATIONS.....	8.0	-	-
Computational Fluid Dynamics	4.0	-	-
Quiet Rotorcraft Systems	4.0	-	-
Total.....	399.8	391.2	354.0

QUESTION 6:

Please provide the budget "levels" broken out by sub-line item (including R&T Base programs) for fiscal years 1986 through 1990 that were provided to OMB. Also, please provide brief descriptions of the work in each level.

ANSWER 6:

See the enclosed table.

QUESTION 7:

How much is contained in the Fiscal Year 1986 request for alternative fuels utilization research, aircraft noise research, wake vortex alleviation, cockpit display of traffic information, scarce materials research, human factors, avionics, controls, laminar flow control, university research, and ATOPs?

ANSWER 7:

	FY 1986 ($ in Millions)
Alternative fuels research	-0- [1/]
Aircraft noise research	10.1 [2/]
Wake vortex alleviation	0.4
Cockpit display of traffic information	-0-
Scarce materials research	0.2
Human factors	10.1 [3/]
Avionics	1.0
Controls	17.3
Laminar flow control	5.3
University research	30.0
Advanced transport operating systems	6.5

[1/] General aviation propulsion systems which can utilize alternate fuels, $2.2 million.

[2/] Includes generic, rotorcraft and propeller acoustics. Does not include $8.0 million in the Advanced Turboprop program Propeller Test Assessment (PTA) element which addresses cabin acoustics and structure-borne noise.

[3/] Includes flight management, reliability enhancement, human engineering methods, and human factors facility operations. Excludes simulation facility operations ($11.9 million).

QUESTION 8:

Please provide data showing the effect of inflation on NASA aeronautical programs since 1980.

ANSWER 8:

The following table compares the Aeronautics funding trend (from 1980 to 1986) with an equivalent value in constant 1986 dollars:

	(Dollars in Millions)						
	1980	1981	1982	1983	1984	1985	1986
Approved Budgets	308.3	271.4	264.8	280.0	315.3	342.4	354.0
Constant 1986 Dollars	423.9	339.3	308.9	314.3	340.9	357.3	354.0

While the Aeronautics budget has been increasing modestly in recent years, the purchasing power has actually decreased.

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of C

MAR 22 1985

Honorable Dan R. Glickman
Chairman
Subcommittee on Transportation, Aviation
and Materials
Committee on Science and Technology
House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

In response to the recommendations of the Congressional Advisory Committee on Aeronautics (CACA), we are responding to your invitation to comment on their findings and advice on program areas for reductions and augmentations. The budget request for FY 1986 is the result of extensive review and deliberation by NASA management and its external advisors as well as our partners in industry and academia who actually perform the R&D. The program contained in our FY 1986 budget request represents our best judgment as to priorities and emphasis, and takes into account such factors as risk, potential, time-frame of readiness, need, prior commitments, and importance of NASA involvement. We feel of course that the program submitted is the one that should be supported. In each of the areas that the Congressional Advisory Committee recommended either a reduction (Numerical Aerodynamic Simulation, Wind Tunnel Test Techniques, Oblique Wing, and Altitude Wind Tunnel) or an augmentation (Rotorcraft, Hot Section Technology, and Composites), we have briefly stated below our reasons for our differing viewpoint.

Numerical Aerodynamic Simulation (NAS)

The NAS program is a five year effort ($110M in FY 1984 dollars) to develop an advanced computational capability including operating system software and remote access, followed by a continuing development activity ($15M/yr in FY 1984 dollars) to maintain it as a world class capability for aeronautical research and development. The planned resources are directly linked to specific technical objectives that are phased to ensure that the needed capability evolves in a cost effective and timely manner. NASA already has major multi-year procurements in place, which make the NAS program extremely sensitive to funding variances. If the program does not proceed at the proposed level, the immediate impact will be to delay the Initial Operating Configuration, force renegotiation of these contracts and increase the total

expenditure for this capability. In addition, the remote access system would be sacrificed with the result that we would have a world class capability which no one outside of Ames Research Center could use. These delays would adversely affect our developing national research capbility in a number of areas including a newly emerging computational aeothermodynamics capability for hypersonics and transatmospheric vehicles and computational fluid dynamics. Finally, implementation of the secure area for classified use by NASA and DOD laboratories would be postponed or cancelled with a funding reduction. This would impact our ability to conduct important defense related aeronautical research as R&D funding is required for interfacing equipment.

Wind Tunnel Test Techniques

Over the years, NASA has sustained a research effort directed toward improving wind tunnel testing accuracy. Remaining inaccuracies in wind tunnel testing are due mainly to wall and model sting effects on the flow. It is worth noting that the Aero 2000 Report (National Research Council, 1984) stated that wind tunnels remain the springboard for aerodynamic advances and that improvement in data accuracy is essential, and summarized by indicating that nonintrusive test techniques research, including adaptive walls and model magnetic suspension, should remain strong.

The idea of eliminating model sting interference by magnetically suspending the model is nearing fruition. This has been made possible to a large extent by the development of less expensive, powerful superconducting magnets which permit the suspension and precise control of wind tunnel models. The Langley Research Center's idea of placing the balance inside the model for force measurements rather than sensing the warping of the external magnetic field, is considered a breakthrough and has made possible direct and precise measurements of forces. Magnetic suspension also allows for multi-degree dynamic testing of models at attitudes where sting interference is a maximum. The present research effort of $600K per year is to further develop a small pilot magnetic suspension wind tunnel. Without this NASA effort, a planned United Kingdom pilot facility would then be the only remaining route to perfecting this technology.

The importance of wall interference was aptly illustrated by the CACA's concern of model size limitations in the Altitude Wind Tunnel. NASA is presently exploring two different adaptive wall

concepts for the elimination of wall effects: (1) flexible wall, where the wall is contoured so that streamlines near the model have the same location and shape as if the model was in free air, and (2) porous wall, where air is induced or withdrawn through a fixed wall to obtain the effect in (1) above. Within the next year, pilot tunnels incorporating both these techniques could be operating. The French ONERA T-2 cryogenic wind tunnel already incorporates adaptive walls while utilizing a small test section. This tunnel virtually eliminates wall interference and realizes major economies in power and operating costs.

Oblique Wing Research Aircraft

The planned NASA/Navy Oblique Wing Research Aircraft program is neither a "full scale test program" nor a "large scale manned technology demonstrator." It is a flight research tool to explore, under high speed maneuvering flight conditions, the complex interactions of the combined aerodynamic and aeroelastic wing/aircraft dynamics with the aircraft control system. These complex dynamic interactions can only be replicated in the actual environment of flight and have not and can not be studied in ground based facilities. More wind tunnel testing except in direct support of this specific program is not required.

The F-8 research aircraft was selected as the testbed because of its existing flexible digital flight control system, its simple adaptability for a new wing, and the availability of necessary ground support facilities. The Oblique Wing Research Aircraft is designed to acquire the needed data for technology validation. There is no need to duplicate the "g" environment required for an operational military mission.

The Navy has conducted studies for aircraft for potential fleet defense missions which require both a supersonic dash and long subsonic endurance capability. The results of these studies were reviewed by a Navy constituted Blue Ribbon Committee consisting of Government and industry representatives. The recommendation of this committee was that the Oblique Wing represented a technology option with significant performance advantage and therefore should be carried through supersonic flight validation.

The Oblique Wing program was reviewed and supported by the NASA Aeronautics Advisory Committee and Aeronautics and Space Engineering Board of the National Research Council. Moreover, the CACA recommendation differs from the results of these other outside reviews, and with the CACA ad hoc subcommittee findings.

Altitude Wind Tunnel

The Altitude Wind Tunnel (AWT) program has been endorsed by a substantial number of knowledgeable organizations as fulfilling the critical need for a large scale propulsion systems integration research and test capability with true altitude pressure and temperature. Recognizing the magnitude of the investment required to provide the required capabilities, special care is being taken to validate both the cost projections and technical approach. All recent and relevant experience in the country in the development of large aeronautical facilities has been applied to the review and analysis of the extensive Preliminary Engineering Report, yielding a high degree of confidence in the projected costs and schedules. Extensive analysis, simulation and one tenth scale model testing are underway to insure the AWT flow characteristics and test section features permitting valid test data from high blockage models (up to 12%) are correctly reflected in the final design of the facility as are the unique requirements for aircraft icing research and testing. As a result, the AWT will provide a six fold increase in test section area over the only other icing research tunnel. The 20-foot diameter test section will be larger than any other tunnel that could have been modified for altitude and temperature simulation, even further minimizing blockage effects. Existing data indicates that the unique test section features such as the plenum evacuation system will permit valid test data from full-scale turboprops (14-ft. diameter) and models as large as a full-scale, half-span F-15 with an F-100 engine. Both far exceed the capability of any other facility in the free world.

Rotorcraft

The CACA perceived significant reductions in funding for rotorcraft from FY 1985 to FY 1986. The decrease in funding is not so drastic as perceived and is due primarily to the planned reduction of the ongoing Systems Technology program (-$7.0M) and lack of consensus in the industry on the definition of an appropriate follow-on effort. A significant level of direct rotorcraft research is also supported in the R&T Base.

	FY85	FY86
R&T Base	29.2	31.5
Systems Technology	26.0	20.5
Totals	55.2	52.0

AERONAUTICAL RESEARCH AND TECHNOLOGY
FY 1986 OMB BUDGET SUBMISSION
($ in Millions)

REQUESTED LEVEL	FY 86	FY 87	FY 88	FY 89	FY 90	DESCRIPTION
Aeronautical Research & Technology	391.2	398.9	374.2	356.2	356.7	
Ongoing Program	391.2	398.9	374.2	356.2	356.7	
Research and Technology Base	246.5	260.5	275.6	287.6	298.0	Generic discipline and systems research and technology
Fluid & Thermal Physics R&T	49.6	52.4	55.4	57.8	59.9	
Materials & Structures R&T	29.2	30.9	32.7	34.1	35.3	
Controls & Guidance R&T	13.0	13.7	14.5	15.1	15.6	
Human Factors R&T	10.9	11.5	12.2	12.7	13.2	
Multidisciplinary Research	7.2	7.6	8.1	8.4	8.8	
Computer Science & Applications R&T	21.7	22.9	24.2	25.3	26.2	
Propulsion Systems R&T	25.7	27.2	28.8	30.1	31.2	
Rotorcraft R&T	29.7	31.4	33.2	34.7	35.9	
High-Performance Aircraft R&T	38.8	41.0	43.3	45.2	46.8	
Subsonic Aircraft R&T	20.7	21.9	23.2	24.2	25.1	
Rotorcraft Systems Technology	20.5	4.6	-	-	-	Advanced Rotorcraft and X-Wing
High-Performance Aircraft Sys. Tech.	25.9	29.8	20.8	13.3	12.1	High-Performance Flight Research, Turbine Engine Hot Section Technology, Ceramics for Turbine Engines and Oblique Wing Technology
Subsonic Aircraft Systems Technology	25.9	28.6	18.6	10.3	-	Advanced Composite Structures Technology

REQUESTED LEVEL	FY 86	FY 87	FY 88	FY 89	FY 90	DESCRIPTION
Advanced Propulsion Systems Tech.	44.2	45.4	32.5	16.7	17.3	Advanced Turboprop Systems and General Aviation/Commuter Engine Technology
Numerical Aerodynamic Simulation	28.2	30.0	26.7	28.3	29.3	This program is designed to significantly augment the nation's capabilities in computational fluid dynamics and other areas of computational physics by developing a preeminent capability for numerical simulation of aerodynamic flows.

Hot Section Technology (HOST)

Stretch-out of the HOST program has no negative judgments associated with it. There is no intention of eliminating it nor decreasing the level of future years from the FY 1986 estimate. In FY 1981 the HOST program was planned as a 5 year activity totalling $34.5M. Since FY 1981, we have expended $25.2M through FY 1984 and plan to spend an additional $25.8M through FY 1989 for a total of $52.0M.

Composites

In terminating the ACST program, recognition was taken of the previously significant investments by NASA ($160M) in composite structures and the fact that of all the key technologies for transport aircraft, industry was in a better position to apply these previously developed structures technologies to large wing and fuselage components. Fundamental composites research will be continued at a level of about $3.5M per year. The $19M in FY 1985 will be spread over two years to finish the highest priority elements. During that time, we intend to work with the industry to define what effort, if any, should be pursued in the future. It will be a different program than the one that was cancelled and will consider advanced, lightweight structural materials in general, including composites, thermal plastics, advanced metallics, and metal matrix composites. The FY 1985 funding is sufficient to carry the effort to FY 1987, when, depending on the outcome of the present shakedown and overall priorities coming out of our discussions with industry, we would be in a position to request a follow-on program in the budget.

I appreciate the opportunity you have given us to respond for the record.

Sincerely,

John F. Murphy
Assistant Administrator
for Legislative Affairs

cc:
Congressman Tom Lewis